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SOUTH WALES

INSTITUTE OF ENGINEERS.

TRANSACTIONS.

VOL. 1.

1857 to 1859.

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PROCEEDINGS.

29th October, 1857.

The first General Meeting of the Promoters of the South Wales Institute of Engineers, was held at the Castle Assembly Room, Merthyr-Tydfil, on Thursday, 29th October, 1857:

Mr. MENELAUS, in the Chair.

Proposed by Mr. W. Adams and seconded by Mr. E. Rogers, "That Mr. Menelaus be the President for the ensuing year." Carried unanimously.

The following Officers were elected by ballot:

Vice-Presidents:

Mr E. Rogers
" W. Adams
" W, S. Clark
" G. Martin.
" Thos. Evans
" J. P. Roe

Council:

Mr. S. Truran
" R. Bedlington
" E. Williams
" S. B. Rogers
" Daniel Williams
" Josiah Richards
" Cope Pearce
" Huxham
" David Roberts
" Rees H. Rhys
" John Cox
" John James

Treasurer:

Mr. E. Brigden.

Secretary:

Mr. E. Williams.

The Provisional Committee submitted the Regulations which they had drawn up for the Government of the Institute; these were agreed to. (See Book of Regulations.)

The President then delivered his Inaugural Address.

President's Address.

Gentlemen,

The cheap production of iron is one of the most important questions of our time. Not only is iron one of the chief sources of our national wealth and power, but it is the material agent in the rapid march of improvement which marks our age.

Athough it is not intended, I believe, to give to this Institute a purely local character, I have chosen, in this address, to confine myself almost entirely to the consideration of the influence this Society is likely to have upon Engineering connected with the Iron Manufacture. I need make no apology for confining my remarks to this most important subject.

Principally from the fact of our Works being thinly scattered over a wide extent of country, Engineers have been little in the habit of benefitting by each other's experience. Meeting seldom, they have had few opportunities for the interchange of ideas, and every man has been, as it were, working single handed.

I believe that the formation of this Institute will be of great benefit to the manufacturing interests of South Wales. Among its members it embraces a large proportion of the men, in whose hands is the practical management of our great mining and manufacturing operations, upon whose knowledge and skill will depend, in a great measure—in the iron trade—our successful competition with districts, in many respects more favourably situated for cheap production than our own.

We must now make up, by mechanical invention, for the want of those natural advantages we are gradually losing—from the exhaustion of our cheaply worked minerals: and we have even a more difficult condition to meet. The price

of labour is steadily and surely advancing, and machinery must, of necessity, be largely substituted for manual labour.

In your hands is the working out of this change.

The substitution of machinery for manual labour is ever attended with great difficulty, and requires, perhaps, the highest class of engineering skill. The united experience of this Institute will be more likely, however, to solve difficulties as they arise than any amount of individual effort.

It seems to me that our special work is to devise means for lessening and lightening man's labour. Labour is year by year becoming scarcer and dearer. In proportion as education spreads men will be the less willing to become the "hewers of wood and drawers of water"—and properly so. If education is not to be the means of lightening toil and lessening the hours of work, small good will it do—better leave men as they are. Educate a man, you raise and refine his tastes; he aspires to do something higher than mere manual drudgery; he will work with his head a good deal and with his hands a little. You will never make a navvy of him. You must, if you want to use his labour, invent tools and machinery to do his work for him: he will direct a lathe or other machine, and will really do with such help as much work as ten men would have done thirty years ago with hand tools; but put, when occasion requires, the old tools into his hands, you will find he is no match for the fitter of the old school. This arises from no want of expertness in handling the tools, but from the fact that the man is disinclined to use the physical exertion necessary to get through a large amount of work.

These are the men who are to be the iron makers of the next generation, and it will be wise policy to provide tools for them in time.

I do not mean that education begets laziness—far from it; but it is certain that our heaviest descriptions of labour become distasteful to men who have been even partially educated. Our best boys do not become puddlers and colliers—the tendency is towards the pattern and fitting shops; they aspire to be makers or directors of machinery. I believe this to be a perfectly healthy feeling, which must be accepted and provided for.

I do not shut my eyes to the great difficulty of applying machinery to mining and the various processes connected with iron making.

In mining your operations are spread over a wide field—the conditions are constantly changing. An adaptation of machinery that would suit the work to-day, would require modification to-morrow; and even supposing your labour-saving machinery invented and perfected, from whence is the power for working

the machine to be obtained. On the surface, also, your operations are widely spread. You have the same difficulty of carrying power to the work, and the work to be done is in almost endless variety; and although, upon the whole, the amount of work is great, generally no large portion is done on one spot. Even when you have got your material into the shape of wrought iron, and your operations are conducted within comparatively small limits, the difficulties hardly diminish. In its manipulation the material passes over considerable space—its movements must be rapid—no one movement is precisely a repetition of the one preceding, thus ordinary mechanical means are not applicable; and to increase the difficulty the material generally must be handled while at a high heat.

If we consider, however, what has been done in other branches of manufacture, the great ingenuity that has been displayed in designing machinery for our factories, surely the same amount of skill and invention brought to bear upon our mines and manufactures must produce an amount of labour-saving machinery that will more than compensate for the rapidly increasing value of labour—reduce the amount of drudgery and hard work, and keep the price of iron within reasonable limits.

I approach the next portion of my subject with extreme diffidence. Nothing is so difficult as to indicate truly the road to improvement. In venturing to lay before you my ideas on the subject, I do not forget that I am addressing men, many of whom are older, and have had far larger experience than myself, and who are better qualified than I am to give direction to this movement.

Power with us is cheaply produced; but we want some means of conveying it through the ramifications of a mine, and over the surface of the works. We want a medium for transmitting power that shall be costless, infinitely flexible, and easy of application and management. Having such a means of transmitting power, the numerous applications of which it would be susceptible, would largely reduce the cost of production, by enabling us to substitute machinery for and in aid of labour.

As a means of transmitting power we seem at present to be confined to either water or air under pressure. When the work to be done is the moving of materials through short distances, either vertically or horizontally, no doubt water is the best medium; but when continuous rotatory motion is required, water, as yet, has failed, and compressed air seems to be our only substitute. Of course I am dealing with cases where steam is supposed to be out of the question.

I may mention that compressed air has been successfully used in Scotland. It is carried from the surface down a shaft, and for a considerable

distance underground, to a winding engine, where it is applied in the same way as steam. We are erecting some machinery upon this principle, at Dowlais, for pumping from the bottom of one of our drifts. By our next meeting I hope to be able to communicate to the Institute the result of the experiment.

In the use of air as a medium for transmitting power, the waste, no doubt, will be considerable; but where power can be so cheaply produced, as with us, the objection has small weight.

Presuming we have at command a cheap and flexible power, the problem of a coal cutting machine will be easier of solution. I am not sanguine enough to hope to see invented what is generally understood by a coal cutting machine, that is, a machine to do the work of the collier; but I do hope to see some means introduced for lightening his labour and rendering it less irksome, and whereby he can send out a much larger quantity of coal than he now does.

It is one of the tendencies of machinery to make the rate of production regular. Upon this condition largely depends the economy of manufacture. No class of men work so regularly as those upon whose labour or supervision the productive power of machinery depends; and the nearer connection you establish between the workman and the machine, the more regularly, as a rule, does he attend to his duties. This is a most important element in estimating the value of machinery—substituted for or aiding manual labour. To ensure a man's steady attention to work it is only necessary to increase his direct responsibility: let as much as possible depend upon individual attention and regularity, and you ensure generally a steady performance of duty.

Having such a power at command as I have indicated, if you do not succeed in doing much in the way of saving manual labour, you can, at least, do a great deal in substituting machinery for horses. The great difficulty in this case has been, that in using steam you cannot, as a rule, bring your power sufficiently near the work—your machinery is generally complicated and expensive. You keep in motion, in many cases, a large amount of useless matter, in the shape of rope or chain, unnecessarily absorbing power and largely increasing the expense of wear and tear.

The cost of minerals make up such a large proportion of the cost of finished iron, that economy in this department is of the greatest importance. In mining the operations are purely mechanical: and on the fitness and perfection of the machinery applied will depend, in a great measure, the expense of the material produced.

A portion of the machinery used in the mining operations, connected with the iron works, is far from being perfect. I allude to our trams and roads. There may be exceptions, but in general they are discreditable to the

engineering skill of the district. I fear, in this particular, we have retrograded. Our grandfathers, I believe, beat us in cheap hauling. A well designed coal tram is of far more importance to the economy of a work than a well-designed winding engine.

When we have got our materials to the surface, do we, in the subsequent processes, make the most of them? Is every ton of coal made to do a fair amount of work?

Unfortunately every stage of the manufacture is attended with fearful waste. In the Blast Furnace we use twice the amount of fuel that chemistry tells us is necessary for the reduction of the ore. Even a considerable per centage of the iron itself is sent to the tip in the cinder. In refining and puddling we convert from 10 to 20 per cent. of the pig into a bad description of ore that goes back into the Blast Furnace to deterioate the quality of the iron produced. In the mill, where the operation is merely mechanically changing the form of the material, we lose again 15 per cent. of the iron operated upon.

I do not mean these remarks as a reflection on the skill of iron makers. I believe there is as large an amount of engineering and other ability employed in the iron trade as in any single manufacture in the kingdom. I merely wish to shew what a wide field there is for improvement.

In our Blast Furnaces the cost of labour bears a small proportion to the value of the material produced. In well-arranged works there seems to be little room for improvement in this element of expense. Still with our largely increasing makes, no arrangement for lightening the labour of the men should be neglected, as at present the measure of a man's strength in some instances regulates the quantity made. The great element of waste in the blast furnace is in the quantity of fuel used. Within the last ten years the makes of our furnaces have been largely increased, and the yield of fuel has, I believe, been generally improved. Not many years since 120 tons per week was considered good work for a blast furnace, now 200 tons is a common make, and we are looking forward to 300 tons as the next step in this direction. As I have said there has been also considerable improvement in the yield of coal. The improvement, however, has not been in proportion to the increase of make. It is sometimes argued, that to obtain a large make you must sacrifice yield and quality. In a properly constructed furnace, with sufficient blast, at a proper density, you need sacrifice neither. No doubt if, from an old worn out furnace, that, for years, perhaps, has been a mere vehicle for destroying fuel, you attempt to get large makes, good yields, and fair quality, you will meet with disappointment. You cannot expect to make iron in a lime-kiln.

I have been furnished with an account shewing the furnace makes and yield of coal, in one of the neighbouring works. The gentleman managing

the furnaces is a member of this Institute. From a feeling of modesty he pledged me not to introduce his name. The average make per furnace, for the year ending March, 1857, was upwards of 212½ tons per week, long weight—that is, 21 cwt. of 120 lbs. to the ton. The quantity of coal used, including engines, hot blast, and kilns, was 1 ton 2 cwt. 3 qrs. We have been long told that a ton of coal ought to produce a ton of iron. Here we have it nearly realized. With such an example surely we are not to remain satisfied with the work we are doing generally.

I believe we are on the eve of a complete revolution in blast furnace management. No part of the business of iron making is of such importance as the management of furnaces. Upon the economy of the furnace depends almost entirely the cost of producing finished iron. No after skill can repair the mistakes made in this department. This Institute, I hope, will be the means of collecting a large amount of experience and information on the subject of blast furnaces, and I trust, in a few years, we shall see the fruits in makes doubled, and in yields of fuel reduced, at least, one half.

Puddling has remained, I may say, since its invention, almost without improvement, if I except that of our friend Mr. S. B. Rogers. Science and practice have alike failed in materially improving the process. Here is a process which absolutely costs nearly one half of the value of the material operated upon, to change very slightly its chemical condition, a large proportion of the cost being for manual labour of the most severe kind, of which the supply barely keeps pace with the demand. When iron makers went mad with excitement about the Bessemer invention it was only an indication of how strongly they felt the necessity for improvement. Notwithstanding the failure of nearly all the attempts at improvement, I cannot believe but that the process of puddling is capable of such modification as will materially lessen the amount of manual labour, lessen also the quantity of fuel used, and render the result of the operation more certain as regards quality, for this we have now to depend almost entirely, not merely upon the skill, but also upon the honesty of the workman. We cannot always command both these qualities in the puddler, the result is, therefore, most uncertain. Next to the blast furnace, puddling is the most important branch of the iron manufacture, and at present presents a fine field for inventive skill.

In the mill most of the operations are merely mechanical, and machinery may be applied to reduce largely the amount of manual labour. A large portion of the Ballers' and Helpers' work, in a rail mill, is charging and drawing: that work, I think, might be lightened by mechanical helps. In blooming an arrangement of rolls might be introduced to save entirely the labour of the Bloomers. In roughing and rolling again, much may be done in the way of

easing the work of the men. In conveying the rail to the saws, and thence to the bank, the men may be assisted materially by machinery. In cold straightening, skilled labour may, I think, be dispensed with entirely. For straightening all ordinary sections, a machine might be introduced that would produce a straight bar, with so little attention from the workman, that the cost of straightening would be reduced to the mere labour of bringing the rails to the machine and conveying them away when straightened.

I have ventured to indicate some of the improvements which, in my opinion, may be made by the introduction of labour-saving machinery. It is to Chemistry, however, that we must look for the great economies.

I have alluded to the enormous waste of material in the various processes. This is almost purely a chemical question. We have been too much in the habit of sneering at the chemist and his theories. Let us take him into our counsel—put within his reach the best practical experience in the works—give him a fair opportunity of making experiments; remembering always that it is seldom or never that the first or the fiftieth experiment even is crowned with success. It is only by patient investigation, and after repeated failures, that most valuable improvements have been made.

To return to mechanics. Our Engineers are generally placed under most unfavourable circumstances for making improvements. In nearly every instance the engineering establishment has not kept pace with the growth of the works. The Engineer has been required to do with few and often unsuitable tools, a very large amount of work—he is stinted in the number of hands, and they are often untrained lads or mere labourers. With such means he is expected not only to keep in repair a vast amount of machinery, spread over a wide district of country—machinery at all times exposed to risk of breakage, from the peculiar nature of the work, but he must design and execute whatever new works become necessary, from the casting of a tram wheel to the building of a blast engine. In nine cases out of ten his department is overstrained. His whole energies are required to keep the great machine moving—he has little time for reflection. On all emergences the actual presence of the Engineer is necessary, his men are spread over the whole extent of the works, and much of his time is taken up in mere locomotion. If you walk with an Engineer over the works he superintends, he will point out, at almost every step, improvements that would cheapen production; but with his already overtaxed staff, how is he to effect the necessary alterations? Depend upon it the first step in the way of improvement is to enlarge our fitting-shops, give the Engineer modern tools, and a sufficient staff of men, and I will venture to predict, that for every fitter you permanently employ, you will dispense with six men from some other department; or you will save an equivalent in material by the superior condition of your machinery.

I cannot better finish my remarks than by quoting the words of Professor Rankine, President of the Institute of Engineers, in Scotland, in his introductory address at the last Meeting of the Institute. He says, "If I were required to state in one word what constitutes the characteristic of skilful and scientific practice in the useful arts, I should say—ECONOMY. By economy, I do not mean parsimony, or the use of inadequate means towards an end; neither do I mean economy in money only; but economy of means of all sorts—economy of materials, of power, of time. The fact is, that perfect economy in any operation consists in accomplishing the end proposed, by an amount of means just sufficient, without waste."

I trust, gentlemen, that our Institute will not only be the means of introducing economy into our trade, but that it will tend to the cultivation of a kindly feeling amongst us. Mutual assistance begets mutual esteem.

ON THE

MANUFACTURE OF TIN PLATES,

AND THE USE OF A

SUBSTITUTE FOR CHARCOAL AS FUEL IN THE FINERY,

BY

MR. EBENEZER ROGERS.

Some of the earliest historical records refer to the Tin mines of Britain, and to the intelligence and skill of the miners who worked them. The works of Herodotus (450 years B.C.,) and later of Diodorus Siculus, and Pliny; prove the great importance of the Tin mines of this country, more than two thousand years past. Since that time they have been constantly worked, and so far from being exhausted, the Tin mines of Cornwall seem now to be only beginning to open out, and to prove that the store of ore that district contains is practically inexhaustible.

The Government Official Returns, for the year 1856, made under the able superintendence of Mr. Robert Hunt, show that 9,350 tons of tin ore were raised in Great Britain. This quantity is greater than that of any preceding year; and as many of the deep mines in Cornwall are changing from Copper into Tin ore, increased supplies will be obtained to meet any demand. About four-fifths of all the tin ore to supply the world is raised in Great Britain. The same race of men who worked the mines more than 2000 years since, still work them and preserve their customs and nationality.

The art of coating copper with tin seems to have been known at an early period. Pliny refers to this, and from his description it is probable the vessels to be covered were dipped into melted tin, and the "*Vasa Stannea*," of the Romans, were copper vessels

covered with tin. The difficulty of coating iron with tin was, however, much greater; and the processes of hammering the iron into sheets, sufficiently thin, and cleaning the surface, which latter work had often to be done by filing, were serious hindrances to the extensive use of the invention.

The art of tinning iron seems to have been first practised in Bohemia, and about the year 1620 to have been introduced into Saxony.

Beckmann states that, "in the year 1670, a company sent to "Saxony, at their expense, an ingenious man named Andrew "Yarrenton, in order to learn the process of tinning Having "acquired the necessary knowledge, he returned to England "with some German workmen, and manufactured tin plate which "met with general approbation Before the company could carry "on business on an extensive scale, a man of some distinction, "having made himself acquainted with Yarrenton's process, "obtained a patent for this art, and the first undertakers were "obliged to give up their enterprise which had cost them a great "deal of money, and yet no use whatever was made of the patent "which had been obtained." About the year 1720, works for the manufacture of tin plates were established at Pontypool, and these seem to be the earliest of such works in England which were permanently successful.

In 1728 John Payne invented a process for rolling iron. This seems to have, at once, led to the use of the flat or sheet rolls for the manufacture of iron for tin plates; but it is very remarkable that no further progress was made in this discovery of rolling iron until 1783, when Henry Cort invented the grooved rolls. This discovery was not appreciated for some years. Mr. Reynolds, of Ketly, erected Cort's rolls in 1785. In 1790 Henry Cort was engaged by Mr. Richard Crawshay to erect the Mills at Cyfarthfa, and, soon after, this important improvement in the iron manufacture was generally adopted. The writer purposes to give in this paper a short résumé, first, of the process for cleaning and tinning

the iron plate, and after of the methods of preparing the iron for this purpose.

The affinity of Iron for Tin is much greater than generally supposed. The point at which the metals cohere is no doubt an *actual alloy*; and advantage is taken of this by the manufacturers of articles for domestic use, made in iron—as bridle bits, common stirrups, small nails, &c. When the iron, whether wrought or cast, is *perfectly clean and free from rust*, and brought in contact with melted tin, at a high temperature, an alloy seems to be at once formed, protecting the iron from oxidization whilst the tin lasts. Many plans are used for tinning iron articles, of small size, by the manufacturers. One of the common methods of the manufacturers of bridle bits and small ware, in South Staffordshire, is—to clean the surface of the articles, to be tinned, by steeping them for sufficient time in a mixture of sulphuric and muriatic acids, diluted with water then washing them well with water, but taking great care they do not rust, at once placing them in a partially closed stone ware vessel (such as a common bottle), which contains a mixture of tin and muriate of ammonia. This vessel is then placed on a smith's hearth, duly heated, and frequently agitated to secure the complete distribution of the tin over the iron. The articles when thus tinned, are thrown into water to wash away all remains of the sal ammoniac; and lastly, cleaned in hot bran, or saw-dust, to improve the appearance for sale.

The plans of cleaning and preparing the Iron for Tinning, have undergone many changes in the past century. About 1720, the plan of cleaning was to scour the plates with sand and water, and file off the rough parts, then cover with resin, and dip them in the melted Tin. About 1747, the plates were, after being cold rolled, soaked for a week in the lees of bran, which had been allowed to stand in water about ten days, to become, by fermentation, sufficiently acid, and then scoured with sand and water. In 1760, the plates were pickled in dilute muriatic acid, before annealing, and cleaned with dilute sulphuric acid, after being taken out of the bran lees. An improvement of great importance in this process was made about 1745; the inventor seems to have

been Mr. Mosely, who carried on Tin Plate Works, in South Staffordshire. This invention was the use of the grease pot, and, in this department little, if any, improvement has since been made. The plan was introduced into South Wales in 1747, by Mr. John Jenkins, and his descendants are still amongst the principal manufacturers in the trade. The process of cleaning and tinning at some of the best works now is as follows: when the sheet iron leaves the plate mill, and after separating the plates, and sprinkling between each plate a little saw-dust, the effect of which is to keep them separate, they are then immersed, or as technically termed "pickled" in dilute sulphuric acid, and after this, placed in the annealing pot, and left in the furnace about 24 hours; on coming out, the plates are passed through the cold rolls; after passing the cold rolls, the plates seem to have too much the character of steel, and are not sufficiently ductile; to remedy this they are again annealed at a low heat, washed in dilute sulphuric acid, to remove any scale of oxide of iron, and scoured with sand and water; the plates in this state require to be perfectly clean and bright, and may be left for months immersed in pure water without rust or injury; but a few minutes exposure to the air, rusts them. With great care to have them perfectly clean, they are taken to the stow. (See Figure 14.) Taken from right to left.

Figure 1, represents the "Tinman's Pan."
„ 2, „ the "Tin Pot."
„ 3, „ the "Washing or Dipping Pot."
„ 4, „ the "Grease Pot."
„ 5, „ the "Cold Pot."
„ 6, „ the "List Pot."

The "tinman's pan" is full of melted grease, in this the plates are immersed, and left there until all aqueous moisture upon them is evaporated, and they are completely covered with the grease; from this they are taken to the "tin pot," and there plunged into a bath of melted tin, which is covered with grease; but as in this first dipping the alloy is imperfect, and the surface not uniformly covered, the plates are removed to the "dipping or wash pot;" this contains a bath of melted tin covered with grease, and is divided into two compartments; in the larger compartment the plates

are plunged, and left sufficiently long to make the alloy complete, and to separate any superfluous tin which may have adhered to the surface; the workman takes the plate and places it on the table marked B. on the plan, and wipes it on both sides with a brush of hemp; then to take away the marks of the brush, and give a polish to the surface, he dips it in the second compartment of the "wash pot." This last always contains the purest tin, and as it becomes alloyed with the iron it is removed on to the first compartment, and after to the "tin pot." The plate is now removed to the "grease pot," (No. 4): this is filled with melted grease, and requires very skilful management as to the temperature it is to be kept at. The true object is to allow any superfluous tin to run off, and to prevent the alloy, on the surface of the iron plate, cooling quicker than the iron. If this were neglected the face of the plate would be cracked. The plate is removed to the "cold pot," (No. 5): this is filled with tallow, heated to a comparatively low temperature. The use of the grease pots, No. 4 & 5, is the process adopted in practice for annealing the alloyed plates. The "list pot," (No 6), is used for the purpose of removing a small wire of tin, which adheres to the lower edge of the plate in all the foregoing processes. It is a small cast iron bath, kept at a sufficiently high temperature, and covered with tin about one fourth of an inch deep. In this the edges of the plates are dipped, and left until the wire of tin is melted, and then detached by a quick blow on the plate with a stick. The plates are now carefully cleaned with bran to free them from grease. Lastly, they are taken to the sorting room, where every plate is separately examined and classed, and packed in boxes for market as hereafter described.

The tests of quality for tin plates are—Ductility, Strength, and Colour. To obtain these, the iron must be of the best quality, and the manufacture must be conducted with proportionate skill. This necessity will explain to some extent the cause, why nearly all the improvements in working iron, during the past century, have been either originated or first adopted by the tin plate makers and a sketch of the processes used, at different times, in working iron for tin plates, will be, in fact, a history of the trade.

The process of preparing the best or charcoal iron seems to have undergone but little change from 1720 to 1807. The finery, the chafery, and the hammer, were the modes of bringing the iron from the pig to the state of finished bars. The finery was of the exact form of the Figures 4, 5, and 6, but less than those now used. The chafery or hollow fire was, in fact, the same as the present smiths' forge fire, but on a larger scale; and the "*hollow*" or chamber, in which the bloom was heated, was made by coking the coal in the centre with the blast, and taking care not to disturb the mass of coal above, which was used to reverberate the heat produced. Both the finery and chafery were worked by blast.

The hammers were of two descriptions: the forge hammer a heavy mass for shaping the blooms, and the tilt hammer, much lighter, and driven quicker for shaping the bars.

The charge for the finery was about 1½ cwt. of pig iron: this, under the first process, was reduced to 1¼ cwt. It was, when ready, put under the forge hammer, and shaped into a "BLOOM," about two feet long and five inches thick; this was then heated in the chafery, and, under the tilt hammer, drawn out to a "BAR," three to four inches wide, and half-inch thick.

The manufacture up to this point, until a recent period, was carried on by the iron masters, and the iron in this state was sold under the name of "tin bars" to the plate makers. The average price for these bars, from 1780 to 1810, was £21 per ton. The sheet and cold rolls were then in use nearly as at the present time.

In 1807, Mr. Watkin George; whose position had been established, as one of the first engineers of his time, by the erection of the great water wheel and works, at Cyfarthfa, removed to Pontypool, and undertook the re-modelling of the Old Works there. *His genius was equal to the task.* He clearly saw that the secret of the manufacture was, to produce the largest possible quantity, with least possible machinery and labour. His inventions, to this end, worked a complete change in the trade. His

plans were: to first reduce the pig iron in a finery under coke, and then bring this "refiners' metal," (so termed), into the charcoal finery. The charcoal finery was built as shewn in Figures 4, 5, and 6: Figure 4, being a front elevation, Figure 5, a horizontal, and Figure 6, a vertical section.

A charge of 3 cwt. of iron was used in this, and as it became malleable it was reduced under the hammer to what he termed a "STAMP:" this was a piece of iron about one inch thick, and of any shape horizontally. It was next broken in pieces of a convenient size, and about 84lbs were "PILED" on a flat piece of tilted iron, with a handle about four feet long. This rough shovel or holder was called the "PORTAL," or the "STAFF." To re-heat this "PILE" in the chafery would be a work of great cost and difficulty, and the brick hollow fire (as shewn in Figures 7, 8, 9, 10, 11, and 12: Figures 7 and 8 being elevations, and Figures 9, 10, 11, and 12, sections), was invented. This is, the writer believes, one of the inventions, which, although in work during the past fifty years, still points to very great improvements in the manufacture of iron. It is in substance the plan of using the gases produced by the decomposition of fuel for the working of iron.

The *charcoal finery* is also worked by the use of the gases to a much greater extent than is generally known. The workman sends his blast directly into the mass of iron, and the charcoal seems to be simply the means by which he is better enabled to manipulate the iron in the finery, and keep it covered, so as to revive the oxidized metal, and thus prevent waste. A few hours spent with any intelligent workman, at the side of his charcoal finery, would shew the wasteful and expensive character of the so-called "*new*" schemes for converting cast into wrought iron by the use of air alone. The late belief in these schemes, by men of high repute and practical knowledge in the trade, is a direct proof of the deficiency in knowledge, of exact science; as at present applied to the manufacture of iron.

The pile was now placed in the hollow fire, and brought to a soft welding or washing heat—again hammered out to "SLABS,"

six inches wide and three-quarters inch thick—these were re-heated, cut up, and afterwards passed through rolls, reducing them to "BARS" six inches by half-inch. These were known in the trade as "*hollow fire iron*," or "TIN BARS." The result of Mr. Watkin George's improvements was, to reduce the cost, and double the production with the same outlay in machinery. All the tin plates made at this time had the great defect of a rough and smooth side. In the year 1820, Mr. William Daniell, (a gentleman still living, and for whose inventions the trade is and will be under great obligation,) found a mode to remedy this defect. Himself, a maker of tin bars and plates, he had observed that the smooth side of the plate was always that corresponding to the flat part of the "PORTAL," or "STAFF;" he, at once, having ascertained this cause, remedied the defect by hammering out the pile, notching it, and doubling it over, so that the tilted blade of the "staff" was on the top as well as the bottom of the pile. This was the invention of "TOPS AND BOTTOMS," and the writer need not remind the practical men present of the immense sums made by this discovery during the past 37 years.

Another improvement since 1807 is the use of the running out fire: it is still adopted in only a few works. This is represented by Figures 1, 2, and 3. Figure 1 is a front elevation; Figure 2 a horizontal section; and Figure 3 a vertical section. This process saves waste of heat and labour, by running the refined metal at once into the charcoal finery.

The "tin bars" before referred to, six inches by half-inch, are heated and run through rollers, until they form a sheet of sufficient width; this sheet is then doubled, and passed through the rolls, and this repeated until this sheet is quadrupled,—the laminæ are then cut to size, and separated as before described. The writer asks careful attention to the fact, that, the last part of the rolling is done when the iron is nearly cold. These sheets are next annealed, and were formerly bent separately, by hand, into a saddle, forming two sides of a triangle, thus ∧, and placed in a reverberatory furnace, so that the flame should play amongst them, and heat them to redness; they were then plunged into a bath of

muriatic acid, or sulphuric acid, and water for a few minutes, taken out, and drained on the floor, and again heated in a furnace; after which, a scale of oxide of iron separates from the plate, during the work of bending them again straight, on a cast iron block.

The plates should be now free from rust or scale, and are then passed cold through the chilled rolls: this last process is most important, as the ductility and the strength and colour of the tin plate depend upon this; at this point bad iron will crack or split, and any want of quality in the iron, or skill in the manufacture, will be shewn.

A great improvement in the process of annealing was made in 1829, by Mr. Thomas Morgan: the plates were piled on a stand, and covered with a cast iron box, now termed an "annealing pot;" in this they were exposed to a dull red heat in a reverberatory furnace for 24 hours. This annealing pot, with its stand, is represented by Figure 13, in plan and vertical section.

A very important invention in the manufacture of iron for tin plates, and which is yet only partially carried out, was made by Mr. William Daniell, in 1845. About 2½ cwt. of refined metal is placed in the charcoal finery; this is taken out in one lump, put under the hammer and "nobbled," then passed at once through the balling rolls, and reduced to a bar six inches square and about two feet six inches long. This bar is either cut or sawed off in pieces six inches long, and these rolled endways to give a bar about 6 inches wide, 2½ inches thick, and 12 inches long, and in this state the inventor calls it a "BILLET." This is heated in a small balling furnace and rolled down to a bar one-quarter inch thick and eleven inches wide, and will be about six feet long This is taken at once to the tin plate mill, and the process saves great expense in fuel and machinery.

By the old method of annealing, a box of tin plates required about 13lbs of tin. This is now done with about 9lbs. for charcoal and 8lbs for coke plates.

In referring to tin plates the standard for quotation is always taken as 1. C. (Common No. 1.) This is a box containing 225 plates, which should weigh exactly 112lbs.

THE FOLLOWING ARE THE MARKS, WEIGHTS, AND MEASUREMENT, OF THE TIN PLATES NOW IN COMMON USE;—

Names.	Sizes.	No. in a box.	Weight of each box.	Marks on the boxes.
	Inches.		cwt qrs lbs	
Common, No. 1	13¾ by 10	225	1 0 0	C 1
Do. No. 2	13¼ " 9¼	"	0 3 21	C 1 1
Do. No. 3	12¾ " 9½	"	0 3 16	C 1 1 1
Cross, No. 1	13¾ " 10	"	1 1 0	X 1
Two Crosses, No. 1	" "	"	1 1 21	XX 1
Three Crosses, No. 1	" "	"	1 2 14	XXX 1
Four Crosses, No. 1	" "	"	1 3 7	XXXX 1
Common Doubles	16¾ by 12½	100	0 3 21	C D
Cross ditto	" "	"	1 0 14	X D
Two Cross ditto	" "	"	1 1 7	XX D
Three Cross ditto	" "	"	1 2 0	XXX D
Four Cross ditto	" "	"	1 2 21	XXXX D
Common Small Doubles	15 by 11	200	1 2 0	C S D
Cross do. do.	" "	"	1 2 21	X S D
Two Cross do.	" "	"	1 3 14	XX S D
Three do. do.	" "	"	2 0 7	XXX S D
Four do. do.	" "	"	2 1 0	XXXX S D
Waster's Common, No. 1	13¾ by 10	225	1 0 0	W C I
Ditto Cross, No. 1	" "	"	1 1 0	W X I

One of the great items of expense in the manufacture of best iron, as before described, is the cost of charcoal for the fineries. This limits, at present, the production of iron made by these means; but the superior quality of iron made in the charcoal finery is always admitted. About 1850 the attention of the writer was directed to the use of a substitute for charcoal in the finery. Careful thought and experiment led him to the conclusion that some coals could be charred in such a way as to produce a mechanical structure analogous to charcoal, and, at the same time when deprived of sulphur, might he used in the finery. These experiments resulted in the manufacture of a substance the writer names "*charred coal.*" This material has been worked at several of the principal manufactories in the district, and declared equal in every respect to charcoal. Some tin plates made by this process were shewn at the Great Exhibition in 1851; as also the charred coal used in the finery (See the Jurors' Reports, &c) The quality of the plates was admitted as equal to the best charcoal; but the writer refused at that time to explain publicly the process used in the preparation of the "charred coal." *The specimens on the table, of iron, worked with charcoal, and "charred coal," will enable this meeting to form their own judgment of the comparative quality.*

The preparation of the "*charred coal*" is very simple. The coal is first reduced to small, and washed by any of the ordinary means: it is then spread over the bottom of a reverberatory furnace to a depth of about four inches, the bottom of the furnace is first raised to a red heat. When the small coal is thrown over the bottom a great volume of gases is given off, and much ebullition takes place: this ends in the production of a light spongy mass which is turned over in the furnace, and drawn in about one hour and a half. To completely clear off the sulphur, water is now freely sprinkled over the mass until all smell of the sulphuretted hydrogen gas produced ceases The result is "charred coal," as the specimen shewn. The quantities of "charred coal" hitherto produced have been made on the floor of an ordinary coke oven, whilst red hot after drawing the charge of coke. The

following analysis of the coal from which this "charred coal" is made, is extracted from the "Report on the Coals suited to the Steam Navy," by Sir H. De la Beche and Dr. Playfair:—

ABERCARN COAL.

Carbon	81.26
Hydrogen	6.31
Nitrogen	.77
Oxygen	9.96
Sulphur	1.86
Ash	2.04
	102.20

Some points of great practical value may be elicited from this description of, *the manufacture of iron for tin plates;* and a careful study of the specimens before the meeting. It will be noticed the stamp iron is highly crystalline, and falls to pieces under the hammer unless cautiously handled. The pile itself, after heating, is also crystalline and brittle; but after passing through the rolls it becomes less crystalline. When reduced to a sheet it is still less crystalline and more ductile; but after passing the cold rolls all the crystalline character is apparently destroyed, and it becomes a homogenous mass, and very ductile, hard, and tough. The hammering and rolling appears to alter the structure of the iron, and instead of allowing the atoms to arrange themselves in crystals, to bring them into a homogenous or amorphous mass, which is then held together by the law of cohesion, and is more dense and closer than when crystallized. In practice this principle is constantly used. Every smith knows the practical result of what is termed "hammer hardening." All razor blades, and best cutlery, are hammered on the edge until nearly cold. All the steel borers and chisels used for hard work, are, or should be, thus treated, and are known to last very much longer, and take a finer edge.

An example of the cohesive power of iron is given in an able paper on "Decimal Measure," given by Mr Joseph Whitworth, in June last at the meeting of Mechanical Engineers, in Man-

chester: he states, "As an illustration of the importance of very "small differences of size, I have brought an internal guage having "a cylindrical aperture .5770 inch diameter, and two external "guages or solid cylinders, one being .5769 inch, and the other ".5770 inch diameter. The latter is 1-10,000th of an inch larger "than the former, and fits tightly in the internal gauge when both "are clean and dry; while the smaller, .5769 inch gauge, is so "loose in it as to appear not to fit at all. These guages are finished "with great care, and are made true after being case-hardened. "They are so hard that nothing but the diamond will cut them, "except the grinding process, to which they have been subjected "The effect of applying a drop of fine oil to the surfaces of these "guages is very remarkable. It will be observed that the fit of "the larger cylinder becomes more easy, while that of the smaller "becomes more tight. These results shew the necessity for pro-"per lubrication. In the case of the external gauge, .5770 inch "diameter, the external and internal guages are so near in size, "that the one does not go through the other when dry, and, if "pressed in, *there would be danger of the surface particles of the one* "*becoming* IMBEDDED IN OR AMONG *those of the other, which* I HAVE "SEEN HAPPEN, *and then* NO AMOUNT *of force will separate* "*them;* but with a small quantity of oil on their surfaces they "move easily and smoothly. In the case of the external guage, ".5769 inch diameter, which is 1-10,000th of an inch smaller in "diameter than the internal guage, a space of half that quantity "is left between the surfaces; this becomes filled with the oil, "and hence the tighter fitting which is experienced."

When the best wrought iron is melted, the homogenous structure, or what is technically called "fibre," is entirely destroyed, and it assumes a highly crystalline character: the specimen before the meeting, prepared by Mr. Riley, is an example.

After long and careful observation and experiment, the writer finds: That the malleability of iron is produced; *by destroying or preventing the crystalline structure of its atoms, and bringing them into a homogenous state; in which "aggregate" mass, the natural law of "cohesion" prevails.* At present this is accomplished prin-

cipally by *mechanical pressure;* and the result required is produced with greater or less facility by some alloys with the iron, the exact laws and effect of which are at present unknown.

The *true object of repeatedly cutting, piling, re-heating, and rolling in the manufacture of merchant iron, is to produce a series of layers or plates, welded together, in which the crystalline structure is more or less destroyed or prevented.*

DISCUSSION.

Mr. Michell asked if Mr. Rogers meant, that two pieces of iron, however accurately fitted, could be made to cohere and become one solid mass, by mere pressure only, without the aid of friction?

Mr. Rogers replied that, strictly speaking, pressure could not be used without friction. "When separate masses, of like nature, come into close con-"tact with one another, if the surfaces are uneven, the points of contact are "infinitely small, and the cohesive force imperceptible; but, if the bodies "touch each other by large flat surfaces, *e.g.* well polished glass or metal plates, "the number of points of contact is greatly increased, and the cohesion becomes "very evident. *If the surfaces touched at all points, the cohesion of the bodies "would be as powerful in this direction as in any other.*"

These laws were very ably illustrated by Mr. Whitworth's experiments; and, in this case, science had been indebted to practice. With the plain results of these experiments, he would not detain the meeting in supporting them by further proofs.

Mr. Michell stated, that he had seen a perfect state of cohesion produced between two pieces of iron by friction; and that he had seen two pieces fitted so accurately, as to be difficult to separate, in consequence of the exclusion of the atmosphere; but, with all due deference to the authority quoted, for his part, he did not believe it possible by simple pressure, however great.

Mr. Cox gave it as his opinion, that it was to the attraction of cohesion alone, that the adhesion of two highly polished surfaces, if brought in immediate contact, was due; and cited in illustration the fact, well known to plate glass makers, that two plates, ground perfectly true, would, if fitted to each other, sometimes adhere together so firmly that they could not be separated. That this would be the case, if the surfaces could be brought into immediate contact by simple pressure, he conceived there could be no doubt; but, it was the film of air between them which prevented their being so, without being rubbed together, the effect of which was simply to exclude the air. He had also seen a case, where the bearing of a railway wheel, which had been improperly

supplied with oil, and the film between it, and the brass had been pressed out, had become united so firmly, as to twist off and break the axle; the bearing of the shaft and the brass, were afterwards cut vertically, and the section shewed a complete union of the two metals, and they could not be separated by any mechanical force.

Mr. Edward Riley,—In reference to remarks made by Mr. Rogers, on the cohesion of clean surfaces of iron, he saw no reason, why two perfectly plane surfaces of iron, should not unite by the force of cohesion; provided these two surfaces could be made true, and brought together perfectly clean, the intervening air being forced out. He considered that the difficulty was a mechanical one, it being a mechanical question, whether these conditions can be so far carried out in practice, as to bear out what theory (or more properly, analogy) would indicate. We find examples of this cohesive force, more apparent in other metals,—the common one of lead, or the more marked ones of the noble metals: for example, the cold welding of platinum and gold: which metals, from the state of sponge, by simple pressure become quite solid and homogenous; the working of the former metal, being wholly dependent on this property. It might be argued, that the conditions in the two last cases are different; that it is not simply the union of two surfaces, but of many; in fact, a kind of interlacing of fibres: this is questionable; and it is a point, whether several sheets of gold leaf, laid one on the other, by simple pressure, might not be converted into a solid mass. He was of opinion, that they would unite into a solid sheet. With regard to the remark made by Mr. Rogers, on the cleaned tin plates remaining bright for a long time under water; he thought, that this was what might be anticipated, from a tolerably pure and clean iron being immersed in water. He considered that the oxidation of iron in water, was mainly due to electrical action; it being necessary for oxidation, that there should be some substance playing the part of a negative element, ordinary water always containing a certain amount of common and other salts, which would act as the exciting agent. Cast iron is readily acted upon (more especially in sea water), on account of the carbon it contains; a piece of cast iron, sealed in a tube with sea water, *in vacuo*, in the course of a week or ten days, was found to be considerably acted upon, and a deposit of protoxide of iron formed. He knew an instance, where a boiler, being supplied with peaty water, containing a small amount of copper, was, in the course of four years, completely eaten through into holes, pieces of metallic copper being found in the boiler; the copper acting as the negative element. This subject, Mr. Riley hopes to communicate to the society, at some future meeting.

The President said, that, if Mr. Rogers's hopes were realized, his invention would be one of great importance. A cheap substitute for charcoal would be of immense good to the iron trade; it would open up new modes of manufacture, that could not now be attempted, owing to the great cost of charcoal.

With respect to the subject of cohesion, he had had the pleasure of witnessing the very interesting experiments of Mr. Whitworth, at the meeting of mechanical engineers, in June last. He did not think Mr. Whitworth intended the experiment alluded to by Mr. Rogers, to illustrate the law of cohesion; it was simply an example of wonderfully correct fitting, arrived at by the power of delicate measurement. Mr. Whitworth also illustrated, by the experiment, the advantage of proper lubrication.

He thought it hardly fair, to quote Mr. Whitworth as an authority on the law of cohesion, from any expressions in his paper at Manchester.

He doubted the possibility of producing, mechanically, adhesion between two pieces of iron; and Mr. Whitworth's plug, he thought, would be removed more easily than a piece of the solid metal.

On the motion of the President, a vote of thanks was passed to Mr. Rogers, for his valuable paper.

The following paper, by Mr. Parry, of Ebbw Vale, was then read:

MANUFACTURE OF TIN PLATES.

Running Out Fire.

Fig. 1. *Elevation of Front.*

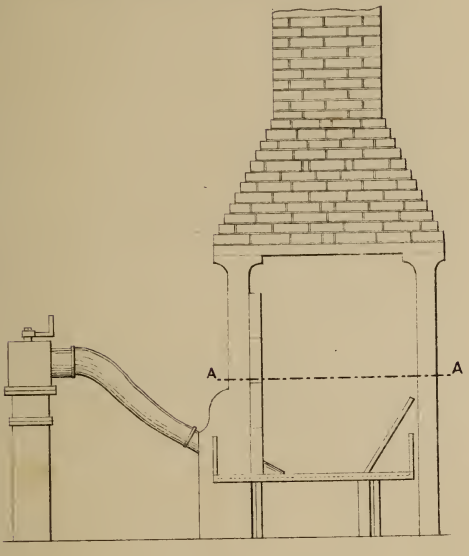


Fig. 2. *Horizontal Section.*

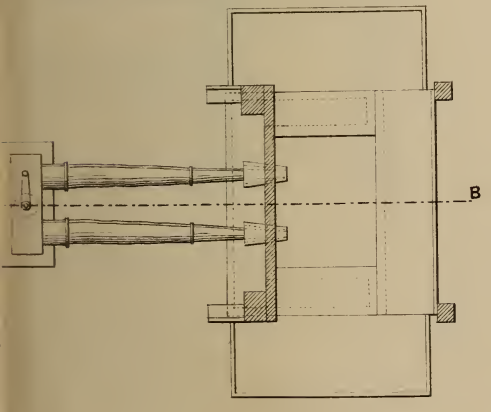
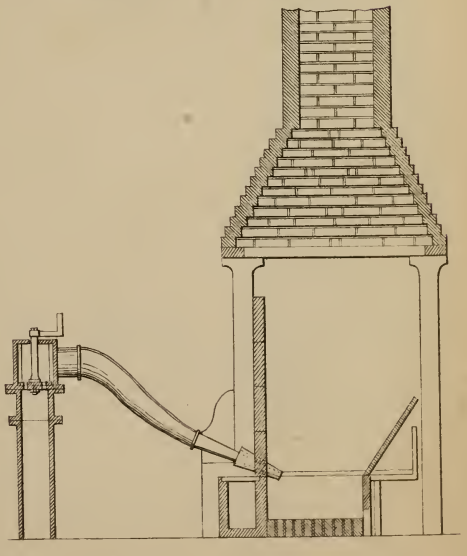


Fig. 3. *Vertical Section.*



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Finery.

Fig. 4. *Elevation of Front.*

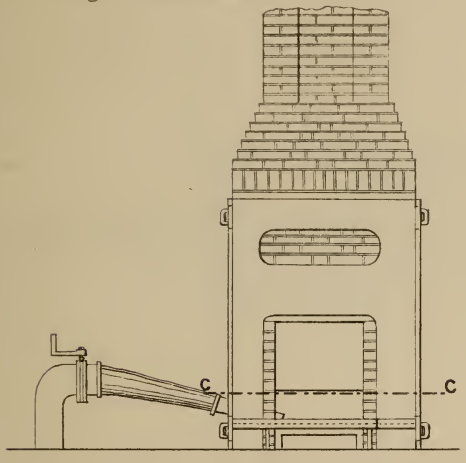


Fig. 5. *Horizontal Section at* C.C.

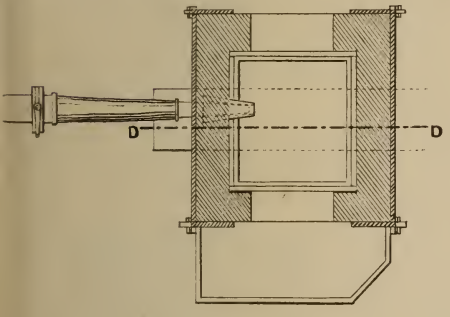
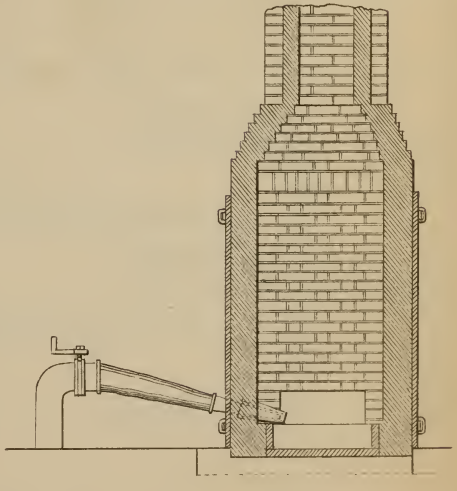


Fig. 6. *Vertical Section at* D.D.



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(Proceedings S.W.I.E. 1858)

Hollow Fire.

Fig 7. *Elevation of Side.*

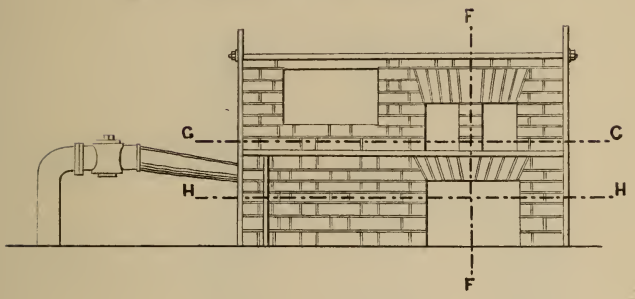


Fig. 8. *Elevation of Front.*

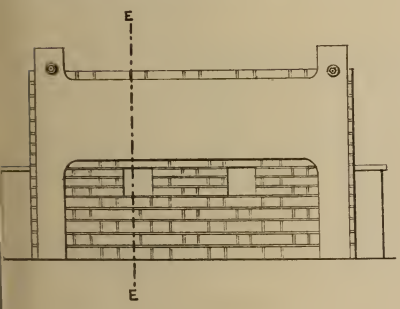
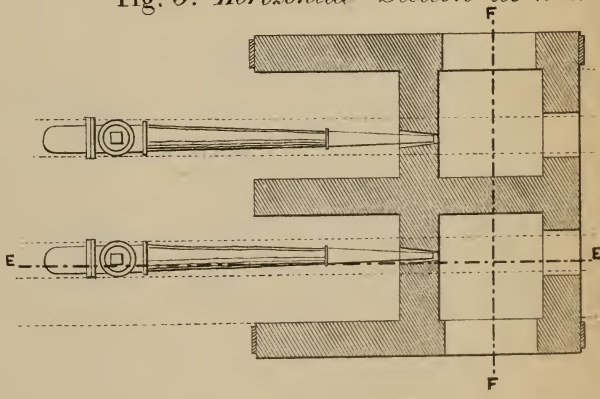


Fig. 9. *Horizontal Section at* H.H.



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(Proceedings S.W.I.E. 1858.)

Hollow Fire.

Fig. 10. *Horizontal Section at* C.C.

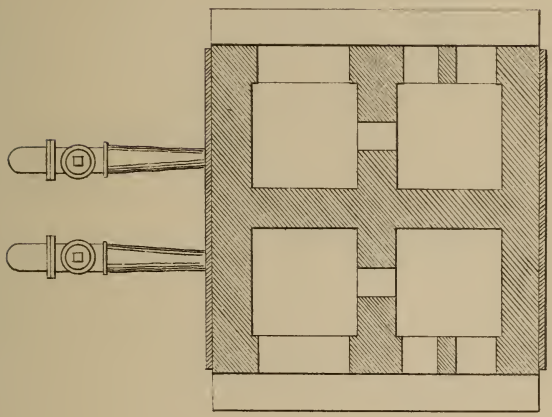


Fig. 11. *Vertical Section at* E.E.

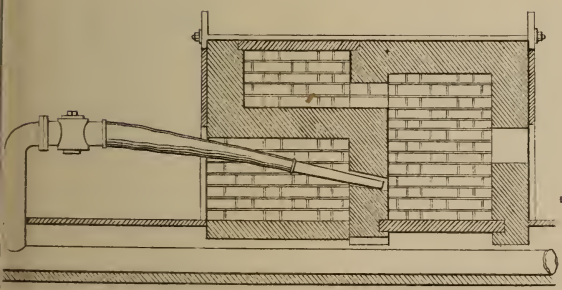
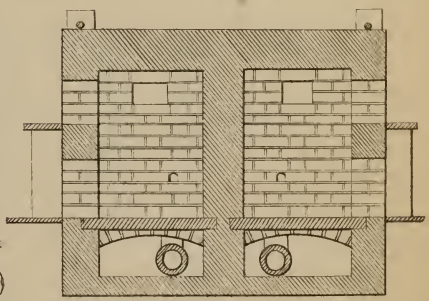


Fig. 12. *Vertical Section at* F.F.



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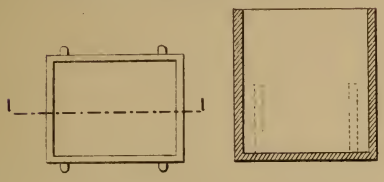
Annealing Pot.

Fig. 13. *Section at I. I.*



Section at J. J.

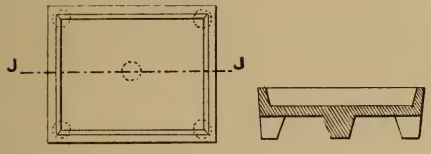


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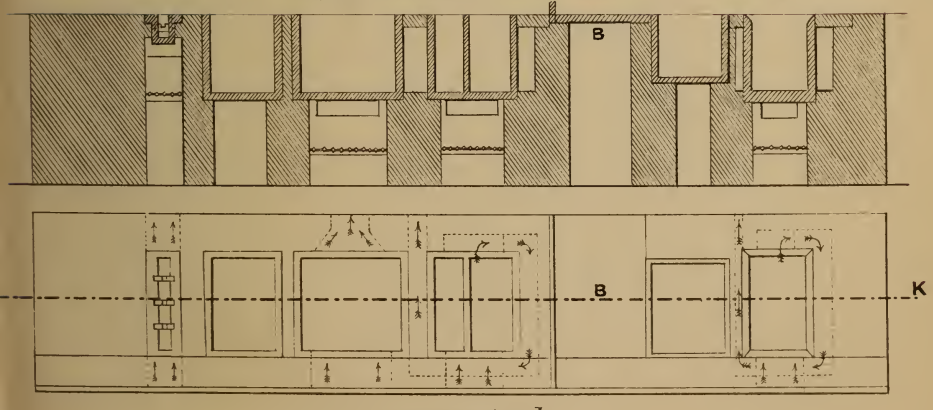
Fig. 14. *Section at K. K.*



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eedings S.W.I.E. 1858.)

ON THE PRINCIPAL CAUSES OF DERANGEMENT

IN THE

WORKING OF BLAST FURNACES,

WHERE THE WASTE GASES ARE ECONOMIZED, WITH SUGGESTIONS FOR THEIR REMOVAL;

INVOLVING CONSIDERATIONS ON THE BEST FORM AND PROPORTIONS FOR

BLAST FURNACES IN GENERAL.

It is now very generally known that furnaces have been found to become much impaired in their action, when the gases are drawn off near the top, and conducted in tubes to distant points, and there consumed for economical purposes, instead of being burnt to waste at the top as usual. Also, that various furnaces have suffered in different degrees, and some to such an extent, that the process had to be completely abandoned. It is likewise thought by many, that the variation in the composition of the ores of different districts, had some connection with those disturbances, the cause of success of the system in one part of the country over another, being attributed to some peculiarity existing in them; and again, that the combustion of the gases, on the face of the minerals, was essential to the successful working of the furnace below.

The object of the writer is to endeavour to show that, when the

gases are collected after they have really left the furnace, and not before, no derangement whatever takes place in its working. To effect this, they must be taken from a chamber constructed above the surface of the minerals; for if taken from any practicable point of the furnace, below that surface, injury, to a greater or lesser extent, follows; owing to the ascending current of heated deoxidizing gases becoming diverted from their usual regular course, which should be at equal velocities over the whole sectional area of the furnace, at any given height. Thus, if the gases are taken off through lateral apertures in the walls, the minerals there will become more highly heated and chemically acted upon than those in the centre; and, if taken from the centre of a furnace, by sinking a pipe in the middle to some depth below the surface, the middle portion would become hotter than the sides, both entailing an injurious effect on the quality of the iron and economy of fuel. This will be made apparent by the following statement of the derangements observed at differently formed furnaces, and the success which attended the means used for their correction.

The first method adopted for collecting the gases was the same as that used on the Continent. An iron tube was sunk into the furnace, seven feet deep, and about three feet less in diameter than the throat, thus leaving an annular space of one and a half foot wide between the walls and iron tube. From this chamber the gases were allowed to pass off by the pressure within the furnace, through a pipe which penetrated the walls. When the tube was kept full of minerals, about one-third or one-fourth only of the gas escaped into the open air, the rest passing into the annular chamber; and when this state of things was continued, scaffolding invariably occurred in the furnace, with the usual accompaniments of black cinder and inferior iron. It is evident, when the tube was kept full of minerals, the contents acted as a loose stopper to the current of hot gases forced up by the pressure from beneath, and diverted them towards the annular space where there was no such resistance, thus leaving the minerals in the central parts of the furnace insufficiently supplied with the upward current, and consequently of caloric. The minerals, on the other

hand, surrounding this cold central core, were furnished with more than the usual proportion of heat, as evidenced by the burning of tuyeres and brickwork in their vicinity. Thus the ores in the external portion of the furnace would become reduced and fully carbonized, while those occupying the central portion would, according to the degree of deviation of the ascending current of heated gases from them, descend to the point of fusion either thoroughly deoxidized and slightly carbonized, or possibly a portion still in the state of oxide; and mixing there with the properly reduced ores, enter into fusion with them, producing a mixture of irons which must necessarily prove of inferior quality, and a black cinder from the unreduced oxides.

When the iron tube, in the throat of the furnace, was kept only partially filled with minerals, much more gas escaped into the open air, as might have been expected, and consequently more traversed the central parts of the furnace; and it was always observed that when this mode of filling was practiced, the furnace worked much better, but a lesser portion of gas was economised. Differently formed furnaces were found to be disturbed in different degrees by the above system of taking off the gases. The old conical narrow-topped furnaces were affected very much less than the improved modern domed-top, of large capacity, where the attempt to take off a large proportion of the gas, by sinking a narrow iron tube into the throat, proved a failure, aud a wider one had to be substituted.

It might be argued that as the same quantity of blast and fuel were used as heretofore, the ascending current of heated gases ought to produce the same deoxydizing and carbonizing effects on the super-incumbent mass, whatever direction they might take in making their escape at the upper region of the furnace, for if the central part should not have been sufficiently acted upon, the external annulus would have had more than its usual share of effects? But when it is considered that iron is only capable of taking up a certain portion of carbon, and no more, it follows that after having received this dose, its further exposure in the external parts of the furnace, where the heated gases abound, cannot induce a more

fit state for alloying with and supplying the deficiency of carbon, existing in that formed in the central parts.

It now appeared plainly that no system of drawing off the gases from a properly shaped furnace around the sides, whether by the insertion of an iron tube into the throat, or by lateral openings through the walls into a chamber surrounding the top, could be adopted without more or less injury to its action, and that some other mode must be devised; and as the disturbance arose from taking the gases at a point beneath the surface of the minerals, and from the sides of the furnace, it appeared that the only unobjectionable method would be to collect them in a *chamber above the surface*, thus equalizing the pressure over the whole area of the mouth, and thereby allowing an equally free flow for the ascending current up the middle as well as sides; in fact, restoring the furnace to its original state, as far as the direction of the flow of heated gases upwards, would not be interfered with by unequal resistance; besides the whole, instead of a portion of the gases, would become utilized. To form this chamber the furnace must be covered, and fed through a hopper. Various forms were proposed, and the one ultimately adopted was a conical charger, similar to that used at Codner Park Iron Works, and figured in the Supplement to Dr. Ure's Dictionary of Arts, 1844, its use there being confined to the supposed advantage to be gained by discharging the minerals around the sides of the furnace. In the present use it forms a very convenient stopper for the top, and any advantage in charging, which might be due to it in feeding an open top furnace, as at Codner Park, would equally apply to the closed top gas furnace. The writer has been informed that a similar mode of charging was in use at the Cyfarthfa Iron Works, in the year 1800, the cone being fixed in the throat of the furnace while the minerals were discharged on its apex from baskets. By this method of charging it will be seen that the larger lumps of materials must roll to the centre of the furnace, and consequently allow a freer passage to the ascending current of gases in that direction. When an apparatus of this description was supplied to one of the old conical form of furnace, with narrow top, for the purpose of collecting the whole of the gases, the trial proved

eminently successful, the furnace producing any quality of iron required, according to the burden, as usual Several other furnaces were similarly furnished in and around the neighbourhood with like results, and it was then the writer's opinion, that the principle of taking the gases from above the surface of the minerals, together with the conical system of charging, were the only indispensible conditions to success for all furnaces; and some even, which were originally built too narrow at the mouth, were improved by the new method of charging, which did not allow of the surface of the minerals rising higher than about six feet of the top, and, consequently, owing to their conical shape, giving them virtually, a wider mouth. Further experience, however, proved the fallacy of this conclusion.

A large domed furnace was furnished with the same kind of charging apparatus which proved so successful in former instances, but the same derangements occurred as in the cases where a portion of the gases were collected by a sunk tube in the throat. It occurred to the writer, as the furnace could not be filled to within six or seven feet of the top, and that at that depth it was 13½ feet in diameter, owing to the sharp sweep of the dome, a new form of furnace altogether was in operation, viz., one of 37 feet in height, instead of 44 feet, with a mouth 13½ feet diameter and not 8 feet as before; and that as the minerals cannot lie so close against the smooth sides of the walls as they do, locked and dovetailed into each other in the more central region of the fur nace, a freer discharge of the gases up the sides must, as a consequence of this, be expected, and in proportion to the respective circumferences of the mouths, or as 25 to 42 On boring a hole through the side of the furnace, about the boshes, this was found to be the case, but to a degree greater than expected. For two feet in, the coke and other minerals were at a white heat; but a little further on towards the centre, lumps of black blazing coal were found, and ironstone which had not even attained a red heat. The charging apparatus was now raised five feet, and the minerals drawn up an inclined plane to the charging cup, enabling the furnace to be kept full to within a short distance of the old mouth, after which it worked as usual. That diminished height alone was

not the cause of irregular working, has since been proved, the furnace having been blown out, for repairs, and re-lined, giving to it the form and proportions deemed necessary from the experience gained—the height being now 37 feet, and the diameter of mouth 7½ feet, or one-half that of the body. The same charger, which failed before, is used, and the furnace, now working five years since the change of form, has turned out a large make of foundry iron, economises the whole of its gas, and is as obedient to the manager as any closed or open top blast furnace can reasonably be expected to be.

Here then the true key to the successful utilization of the gases appears to be found The covering of the top has no effect on the action of a blast furnace kept full to the mouth, and which has the proper form and proportions from thence downwards. The mouth must be understood to be the diameter of that part which represents the mean height of the surface of the minerals. and not the top of the brick work; and the question arises, what proportion should that bear to the widest part, and what the latter should be with reference to the height, to secure a maximum economic effect in the quality of iron made, and the yield of fuel This state of perfection can exist only when the isothermal lines in the furnace are parallel to the horizon—the temperature of the minerals, at any given height, being the same through the whole horizontal sectional area at that height, and, consequently, arriving at the zone of fusion in an equally prepared state We have seen, that if the mouth of a furnace be too wide, the heated gases have a greater tendency to pass up the sides than the centre, thus destroying the horizontality of the lines of equal temperature, and giving them a curved form, having the convex side downward; hence ores, at different temperatures, and of various stages of preparation, will occupy any given horizontal sectional area of the furnace; these descending and mixing in the zone of fusion, will produce evils in proportion to the extent of the deflection of the curves from an horizontal line. On the contrary, if the mouth of a furnace be too narrow in proportion to the other parts, we may expect an undue proportion of the gases to pass up the centre, leaving the minerals around the sides comparatively unacted

upon. It is easy to see that the same evils described in the other case must ensue here, the isothermal lines becoming now concave downwards instead of convex, giving, as before, through any horizontal section of the furnace ores at various temperatures, and at different stages of deoxydation or carbonization, according to the depth they may have attained in the furnace The writer has never met, in the course of his experience, such a case in an extreme degree; but it is recorded, that at the Dowlais Iron Works, a furnace with a six feet mouth and eighteen feet body, proved a failure; but that subsequently the mouth being widened to 9½ feet, satisfactory results were obtained, the make being doubled, while the consumption of fuel per ton of iron was reduced to one-half, besides an improvement in the quality of the latter.

It has already been stated that furnaces originally built with tops too narrow to produce the best effects, were improved in their action by a conical charger, of small diameter; so those having the opposite defect of being too wide at the top, may also be benefitted to a certain extent, provided the walls are nearly perpendicular, or do not widen rapidly downwards, by employing as large a cone as it is possible to work in the throat; for, by the use of this, the minerals must be discharged close to the walls, and the larger lumps roll to the axis of the furnace, and facilitate the passage of gases in that direction, besides giving to the surface of the minerals a concave or cup form, and, consequently, a diminished height and resistance to the upward current in the middle. This principle of improving the charging of such defective furnaces is carried out to some extent in feeding open-top blast furnaces where the gases are lost. The charging-plate is so placed as to prevent the nose of the barrow projecting any distance into the furnace, the minerals being thus discharged close to the edge, the larger lumps roll over to the centre, leaving the smaller at the ring wall to check the upward current there.

In coming to the question of what form and proportions a blast furnace should have to produce the best results in quality of iron and economy of fuel, whether worked with open top, or covered over for the purpose of saving the gases, experience has proved, that when the mouth is one-half the diameter of the

widest part good work is obtained, and that any deviation from this proportion, either way, if in excess, has been productive of serious derangements in its action. It appears, also, that the height of a furnace should bear a certain proportion to the greatest diameter, in order to secure an uniform flow of the ascending current through all its parts; for if the width bear too great a proportion to the height, the boshes must necessarily be of a low angle, and, consequently, the minerals around the sides, near their top, be too great a distance out of the direct line of passage of the ascending current to be properly acted upon by it. The proportions recommended by the writer, and which, in fact, have been practically tested most satisfactorily in several instances, are, for the mouth, half the diameter of the widest part, and this should not be at a less depth than its own diameter. The sides of the furnace to this depth should be formed slightly dome fashion, for the purpose of giving to that region a larger capacity than would be obtained by a conical form. The radius of the curve should be formed by a prolongation of the line representing the greatest diameter; when it is set at a great angle with this line, as is often done to give greater capacity to the dome, the distortion produced by the sharpness of the curve, may leave a segment of minerals unacted upon by the gases in their passage to the mouth, and entail greater evils than would be compensated for by the increased capacity. The curve is continued below the widest part of the furnace till it meets the top of the boshes, the angle of which should not be less than 70°, and start from the point of the tuyeres; the depth also from the widest part to the tuyeres should not be less than its own diameter, *plus* half the diameter at the tuyeres.

These proporions give a blast furnace, of any determinate height fixed upon, the largest possible capacity it is capable of receiving, while remaining free from any distortion of form likely to shelter any portion of the minerals from the action of the upward gaseous current, and is represented in section in figure 1. When the height exceeds the proportion to the greatest diameter, as given above, an unnecessery sacrifice in its capacity is the only loss entailed. The height, above the mouth, when it is intended

to utilize the gases, must, of course, be regulated by the kind of hopper used for charging. The one described, while possessing many advantages, takes up much space in the furnace, and allows of the escape of gas during the introduction of the materials. Probably when the true principle of collecting these gases, with. out injury to the action of the blast furnace, becomes more generally known, attention may be drawn to the contrivance of a charging apparatus, free from those defects.

It will be seen the writer attaches some value to capacity, in a blast furnace, and this is supplied by giving a greater width in proportion to height than is usually done; but, as just shown, unless a contraction of the mouth, to a certain extent, is made, the gases pass up the sides more than in the middle In furnaces, narrow in proportion to height, the derangement, arising from a deviation from the relation laid down of mouth to widest part, are not near so great; for although the gases may predominate in one part of the furnace, still there may be sufficient, in such a case, in those parts where the least supply is furnished, to produce the necessary chemical actions on the ores—the gases, meanwhile, from that portion over supplied, escaping at the mouth, at a higher temperature than they would, if made to act uniformly on a larger mass of minerals. In furnaces of 4200 feet capacity, the writer has found the temperature of the gaseous escape at 640° Fah., but in a larger furnace, of 6000 feet capacity, the temperature was only 360°, showing a difference of 280°. Now, as the effective force of a blast furnace, consists in the *excess* of temperature, generated in the zone of combustion, over and above that required for the fusion of the minerals, it follows, that the addition of these 280° of heat, retained and carried down by the minerals, must play an important part in the economy of fuel used. Thus, supposing the fusing point of the minerals should be 2750° Fah., but that the temperature raised in a cold-blast furnace is 3250°, we have an effective power of 500° to be expended or rendered latent in the liquifaction of the ores. But, if with a hot-blast, the temperature be raised to 3500°, the effective power becomes 750°, or an increase of 50 per cent. on the fusing power of a furnace, making a certain determinate quality of iron,—this is generally known to

be the advantage gained by the use of hot-air. Whether the extra excess of temperature be supplied from above or below, can make no difference in the results obtained; hence the advantage to be expected from a greater absorption of heat by the minerals, from the gases, in a large furnace than a small one,—both supposed to be consuming an equal quantity of fuel, in a given time.

The principle upon which this economy is based, does not appear to have commanded much attention, perhaps, owing to blast furnaces having already, and for some years past, received so large a capacity; or from any increase in it, having been chiefly effected by widening the mouth alone, to an undue extent; thereby neutralising the advantages which ought to have been gained, by causing the gases to become diverted more to the sides of the furnace. When, however, small melting furnaces are enlarged to twice or thrice their former size, the effects become more strikingly apparent; an economy of fuel, to the extent of 150 or 200 per cent. being the practical result. But with a large furnace of as much as 6000 feet capacity, discharging its gases at so low a temperature as 360° Fahrenheit, it becomes questionable whether any further increase would be productive of much benefit, where the same quantity of fuel and volume of air are to be consumed, per hour, as before. The necessarily increased height, would entail a corresponding crushing action on the fuel; which would, in all probability, counteract the effects of the slight increment of temperature which should otherwise attend it. Whereas many furnaces, as usually built, might have had nearly double capacity, with the same height, to very great advantage.

As it is not the purpose of the present paper, to enter generally on the theory of the blast furnace, sufficient only has been gone into, to elucidate the following conclusions, which, it is presumed, we may fairly arrive at.

1st.—That with a properly proportioned furnace, of large capacity, no method can be adopted for collecting the gases, other than from a chamber above the mouth,—that is, after they have virtually left the furnace; the diameter of the charging cone, not being greater than half the diameter of the mouth, so as to ensure an equable distribution of the materials, of all sizes, over the whole surface.

2nd.—That furnaces with tops too narrow to suit the widest part, and where an undue portion of the gases pass up the axis, leaving a segment at the sides comparitively cool, may be improved in their action, by taking off a *certain* portion of gas from the sides, near the top; either by a sunk cylinder of short depth, in the throat, or by lateral openings in the walls. It is obvious, the effect of such arrangements would be to divert a portion of the gases to the sides of the furnace, and raise the temperature there.

3rd.—That in similar furnaces the whole of the gases may be collected, attended by an improvement in the working, by fixing a small conical charger on the top; thus giving to the furnace a diminished height, but a wider mouth. The loss in capacity will be more than compensated, by the proper divergence of the ascending current of heated gases, to the exterior portions of the minerals.

4th.—Conversely, furnaces having tops too wide may also be improved, by collecting a *certain* portion of gas from the axis of the furnace by a sunk tube. The preponderance of the ascending column being, in these cases, around the sides, the convergence of a portion towards the cold central part, must necessarily raise its temperature.

5th.—That with similar furnaces, where the in-walls are nearly perpendicular, the whole of the gases may be economised, by using a large conical charger, which nearly fills the throat. The larger lumps of minerals, rolling to the axis, facilitate the passage of the heated current there; and tend to equalise the temperature of the material, over any given section of the furnace. This will compensate for the loss of capacity, by the space taken up by the charging apparatus, and the furnace will be maintained, at least, in its normal state, if not improved.

6th.—That in the economy of fuel and quality of iron produced, it is a matter of much greater consequence the gases should, after they have left the upper limit of the zone of fusion, communicate an equal degree of heat, and, consequently, induce an equivalent chemical change in the superincumbent mass, over the whole section, at any given depth; than, that by an enlargement of the capacity, with a view of absorbing more heat from the ascending current, they should cease to fulfil those conditions.

7th.—But, that these conditions being maintained, the larger the capacity of the furnace, the greater must be the economy of fuel.

8th.—That the effect of the conical system of charging, is limited, to a certain extent; it not being found sufficient to correct the tendency to the passage of gases, up the sides of the furnace, where a diminished height an an excessive increase of mouth occurs,—as exemplified in figure 3.

9th.—That in tall *narrow* furnaces of comparitively small capacity, in proportion to the volume of blast passed through them, any system of taking off the gases at or near the top, may be adopted without injury to the usual quality

of iron produced; owing to the presence of a superabundant supply, through all parts of the furnace,, of deoxydizing and carbonizing gases at a higher temperature, to effect the requisite chemical changes in the ores, before fusion; while, at the same time, any deviation of the upward current, from its usual course in the upper part of such a furnace, will not extend its influence to so great a depth as in a wider one; or in other words, a deflection of the isothermal lines from the horizontal position will not commence, till a high point in the furnace is attained. But a loss of fuel, equivalent to a certain diminution of capacity, must be entailed.

10th.—That in the erection of new blast furnaces, or in the re-lining of old ones, arrangements may be made for the collection of the whole of the gases, with certainty of success; and that the same may be effected with the majority of furnaces already erected.

Figure 1, Plate 6, shows a section of the interior of a blast furnace, of the form and proportions suggested by the writer, surmounted by a gas chamber and charging apparatus, for the collection of the whole of the gases.

Figure 2, Plate 7. A large furnace, with a cylinder of small diameter sunk in the throat, where nearly the whole of the gases passed up the sides, causing excessive derangements in its working; but when the lower end of the cylinder was enlarged to 9½ feet, the top remaining the same, less gas was collected, but an improvement in the action of the furnace ensued.

Figure 3, Plate 8. A similar furnace, charged by a conical stopper, giving to it a diminished height of 7 feet, and a mouth increased to 13½ feet diameter, where also it was ascertained the gases passed in undue proportions up the sides, causing the like irregularities.

Figure 4, Plate 9. The same furnace as Figure 2, but now surmounted by a chamber for collecting the gases, above the surface of the minerals, which were filled to the level of the old mouth. By this arrangement, the whole of the gases were economised, and the former good action of the furnace fully restored, both in economy of fuel and quality of metal.

DISCUSSION.

Mr. Roberts, of Rhymney, said that he, in the course of his experience, had arrived at much the same conclusions as Mr. Parry. He thought furnaces were injured by being made too wide at the mouth, and would give one instance in particular, where a furnace under his charge, which he had had widened to 14 feet 6 inches, worked badly, and was only got right again by narrowing it in to 10 feet. Previous to altering the top to 10 feet, the charges were tipped from the barrows on the charging plates, outside the furnace, and then thrown in with a shovel. As long as this was continued the furnace worked well, but, as soon as ordinary charging was returned to,—that is, tipping direct from the barrows, an alteration for the worse was the result; proving clearly, that the bad working of the furnace, could only be due to the method of filling. As regarded the exact internal form, he was not inclined to attach as much importance to it as Mr. Parry did, and he recollected furnaces that had worked well to the last, making large quantities of good iron at a fair yield, but which, when blown out, proved to have assumed very strange shapes. One of these, at Dowlais, which had been built about 6 feet across the hearth, had worn away to about double that size; while the angles of the boshes and other dimensions, had become greatly changed.

With respect to the collection and utilization of the gases, their first attempts at Rhymney had been far from successful, and he had, at one time, been much opposed to the system; longer experience, however, and altering the sizes of the throat, cone, &c., had proved the objections to be ill-founded, and they now, at some of the furnaces, collected the whole of the gases, which they used to get up steam for their blast engines; effecting great economy of fuel, while the furnaces themselves worked well, were perfectly manageable, and made iron of any required quality, at pleasure.

Mr. James, of Blainau, thought the only limit to the size of the mouth of a blast furnace, was the possibility of filling it properly. With a very wide furnace it was not easy to keep the top closed, and he was inclined to think that what was gained by increased size, was more than lost by not being able to fill properly, or utilize the gases. He believed form was not a matter of much moment, but, in the upper regions of the furnace, attached great importance to capacity, and believed the true way to make pigs economically was very much to enlarge the blast furnace; of course making the pillar of blast suit. Under this belief they were now building, at Cwmcelin, a furnace 68 feet high and 24 feet across the boshes. He was far from believing this large furnace large

enough; indeed, he saw no good reason why the whole make of an Iron Work, however extensive, might not be turned out of a single furnace of suitable dimensions; and that at a less cost than by the present mode of using many furnaces, each making a small quantity. It had been remarked by some gentleman present, that closed top furnaces worked much better with large cones than small ones. He believed it to be in consequence of the better form given by the large cone to the surface of the materials; that is a concave form in lieu of a convex one, causing the large lumps of fuel to roll to the centre of the furnace, and producing there concentrated heat where most required.

Mr. Jones, of Dowlais, recollected the furnace spoken of by Mr. Roberts, which worked exceedingly well in all respects, and was only blown out because a portion of the side wall had fallen, and the remainder become dangerous. He had seen a very notable instance of the non-importance of exact internal shape in the case of one of the Aberdare furnaces, now out, but which had continued to do very good work notwithstanding great wear and alteration in shape. He was in favour of wide throats and boshes of about an angle of about 75 degrees.

Mr. Hosgood, of Aberdare, described the furnace alluded to by Mr. Jones, which had been making about 200 tons per week, of good forge pigs, for many months previous to its being blown out. The width of the hearth, which was originally 7 feet had become 13 feet 6 inches, the boshes were completely gone, and scarcely a vestige of the original shape remained. They had lately blown in a furnace at Abernant of the following dimensions:—Height 43 feet, diameter at top 10 feet, boshes 20 feet, and hearth 8 feet, from which large makes were expected.

Mr. Thomas Evans asked what the pillar of blast was at the first-named furnace, and Mr. Hosgood replied from 4lbs. to 4½lbs., to which, in a great measure, he attributed the large makes.

Mr. S. B. Rogers, of Newport, Mon., did not believe it mattered much what the exact form of a blast furnace was. The thing itself was a mere receptacle in which certain chemical operations were carried on, and the form of the apparatus was, in his opinion, not very material, so that the materials operated upon therein were in due proportions to fuze and react upon each other at a proper working temperature, and thereby prevent "scaffoldings" or other injurious impediments to the smelting operations. He considered the making of pig iron the most important department of an iron work; one upon the proper management of which depended the economy and success of all the after processes as well as the value of the finished iron.

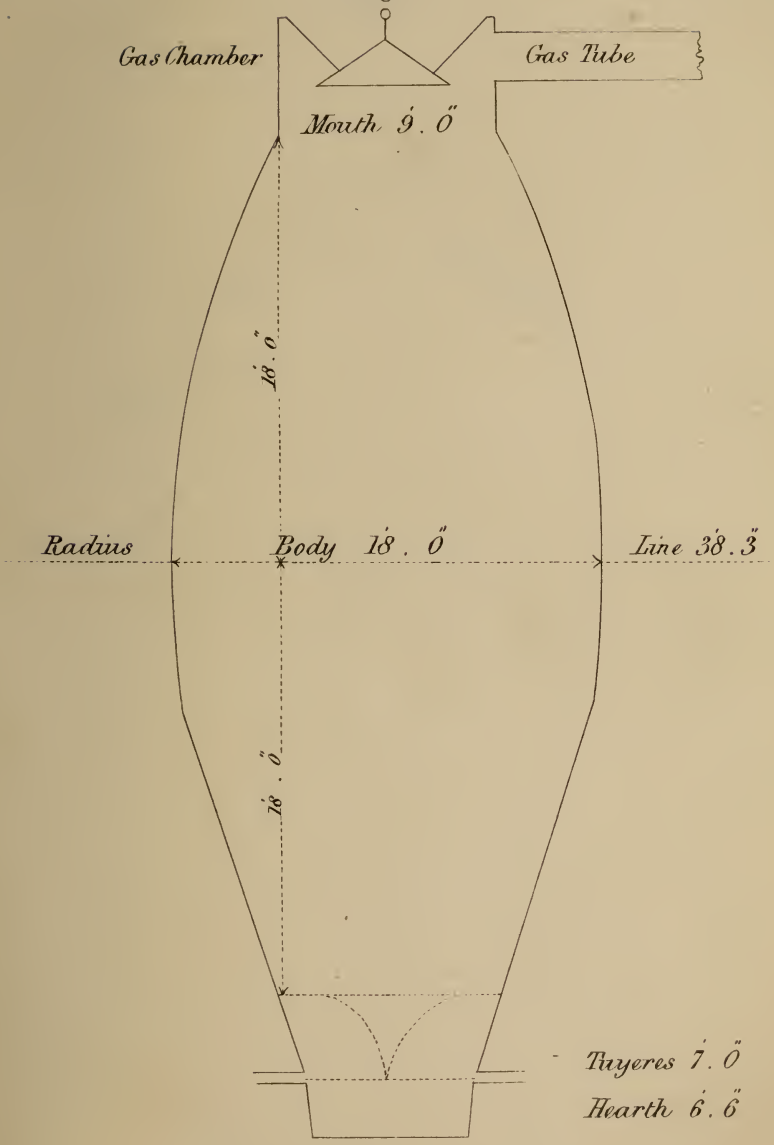
The President was of opinion that internal form had much to do with the working of blast furnaces. Instances of furnaces doing good work, under extraordinary conditions, had been mentioned; but he thought, that as a rule, it

would be found that furnaces which retained their original shape the longest did the best work, if the normal shape had been a correct one. The best shape for particular materials was, he thought, a question of experience. Mr. Parry gave as a rule, half the diameter of the boshes for the width of the throat. This shape he had no doubt was suitable for the Ebbw Vale fuel; at Dowlais, however, they had been led by experience to adopt a very different form. There the tops of the furnaces had been widened: some of them to from 14 to 15 feet across; and the widest-mouthed furnaces generally did the best work. This form had been arrived at by experience, and they had been, for years, gradually increasing the size of their furnaces at top, and so satisfied were they of the merit of wide tops, that a furnace was now building which would be 20 feet in diameter at the mouth. This furnace, like the one at Cwmcelin, would be upwards of 60 feet high. He thought, with Mr. James, that large furnaces, making great quantities, would be found the most economical.

The President said that Mr. Parry deserved the best thanks of the meeting for his able and interesting paper. Mr. Parry had made the operations of the blast furnace his peculiar study, and his opinions on the subject were of great value.

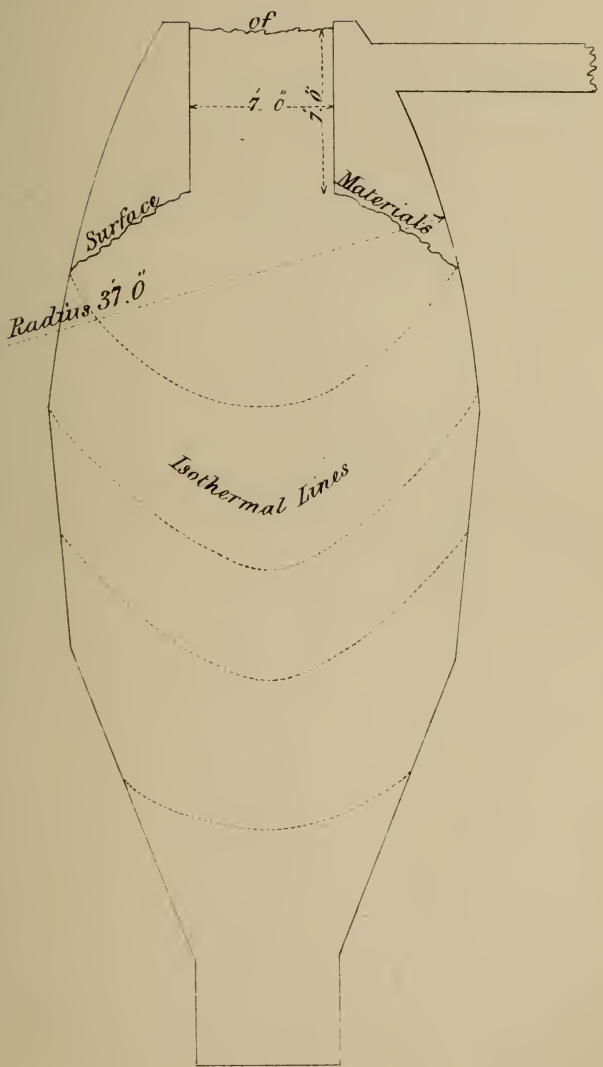
A vote of thanks was passed to Mr. Parry, and the meeting separated.

Fig. 1.



Scale 1/8 of in. = 1 Foot.

Fig. 2.



Scale 7/8 of in. = 1 Foot.

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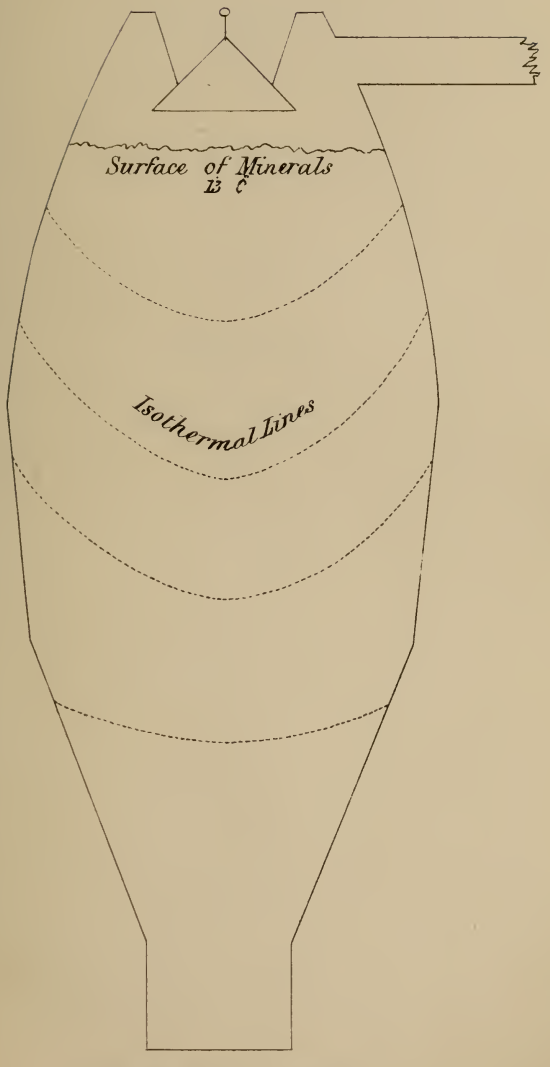
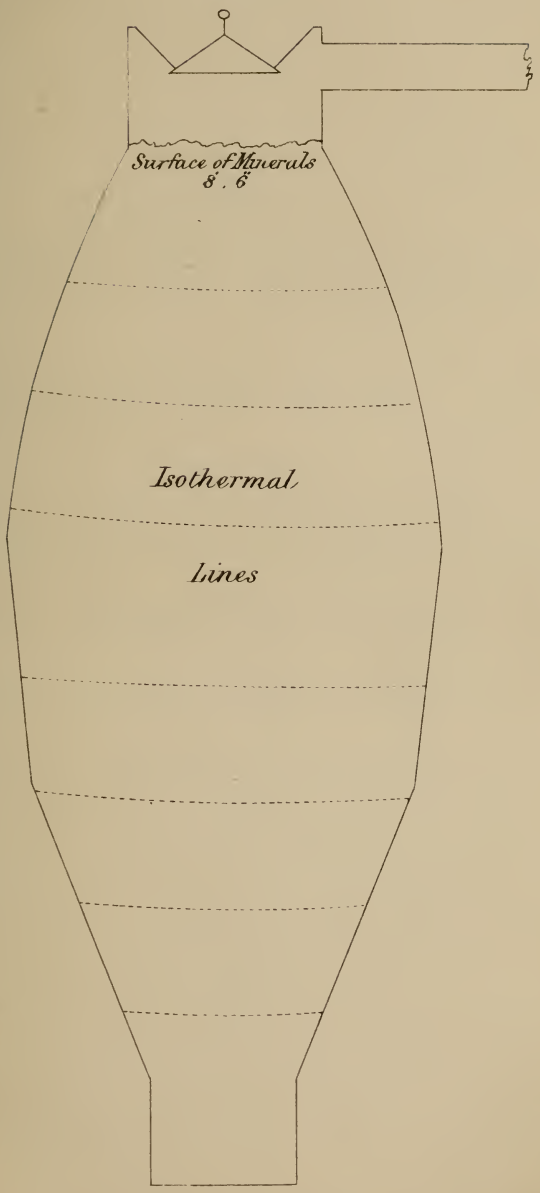
Fig. 3.



Scale ⅛ of in. = 1 Foot.

Fig. 4.



Scale ⅛ of in. = 1 Foot.

SOUTH WALES

INSTITUTE OF ENGINEERS.

PROCEEDINGS APRIL 21st, 1858.

The Second General Meeting of the Members was held at the Temperance Hall, Merthyr Tydfil, on Wednesday, 21st April, 1858;

The PRESIDENT in the Chair.

The Minutes of the last Meeting having been signed,

The President said he was glad to be able to inform the Institute that the experiment mentioned by him at the last meeting of using compressed air as a means of transmitting power had been completely successful. An engine was now at work at Dowlais on this principle, and answered the purpose for which it was intended admirably. The air was compressed by the winding engine, at the top of the pit, and was conveyed through $3\frac{1}{2}$ inch wrought iron pipes a distance of seven hundred yards to the bottom of a drift, where it was used in the same way as steam, in an engine a drawing of which was exhibited. He thought the result of this trial of great importance as a means of introducing an economy into mining

operations. The engine was daily at work in the Dowlais Colliery, and he would be happy to give any gentleman, who felt an interest in the matter, an opportunity of seeing it.

The Secretary then read the following paper—

ON THE ACTION OF PEATY WATER, CONTAINING COPPER, ON A BOILER.

By Mr. RILEY, of Dowlais.

The Author's attention was drawn, in the spring of 1854, to the corrosion of a boiler used at the Rhes Las Pit, a portion of the plate of which is exhibited. On examination of the water, boiler, &c., it was found that a sediment of peroxide of iron was constantly blown off at the gauge cocks to such an extent that all objects, to the distance of some yards from the boiler, were covered with a red deposit of peroxide of iron.

The first object was to examine the water, a careful analysis of which was made: the composition per imperial gallon being—

Silica	.405
Peroxide of Iron.....	.240
Sulphate of Iron	.201
Alumina	.126
Phosphate of Lime	.127
Sulphate of Lime	.350
Sulphate of Magnesia.....	.360
Alkaline Chlorides...	.487
Sulphate of Soda	.258
	2.554

Traces of Copper and a large quantity of Peaty Matter.

On looking at the analysis the following points may be observed:—First, As regards the amount of Silica, Alumina, and Iron, it is evident from the cloudiness of the water analysed, a large portion of these ingredients were held in suspension—as clay. As regards the iron, a certain amount of which exists as peroxide, is probably held in solution by the large amount of peaty matter present. The other portion exists as sulphate of iron (green vitriol), formed by the oxidation of iron pyrytes in the peat. The copper from the same source, and in the same state, was only detected as a trace in a gallon of water evaporated to a very small bulk.

The boiler was new in 1849, and was orginally made of 9-16ths plate. On examining it internally a large amount of sediment was found, composed chiefly of peroxide of iron in a fine state of division, mixed with small pieces of rounded coal and other light material. On drying this residue small pieces of metallic copper were found. The action on the boiler seemed to commence at the water line, and increase in waves, forming distinct lines to the bottom, where the action was the greatest, more especially towards the portion of the boiler exposed to the fire. In some instances scales of oxide of iron were found, from $\frac{3}{8}$ to $\frac{1}{2}$ in. in diameter, with a piece of metallic copper in the centre. The peroxide of iron blown from the cocks with the water was found to contain a small quantity of copper, existing most propably in a minute state of division.

The action of this water on the boiler may be attributed firstly to the action of sulphate of copper (existing as a trace), the copper being precipitated on the iron, and sulphate of iron formed; and secondly, a galvanic action which immediately commences between the two metals, the iron being dissolved by the action of the salts present, which are constantly being concentrated by evaporation, and their action facilitated by the high temperature. It even becomes a question whether, at such a temperature, the water itself may not be decomposed, and furnish oxygen to the iron.

Some experiments have been made in the boiler: a sheet of commercial zinc (cast from spelter) $6\frac{1}{4}$ inches thick by 4 feet long, was rivetted on to a sheet of iron, the latter being a foot longer at each end, so that a portion might be above the water line. After

an exposure of six weeks the zinc was completely broken up and acted on to a considerable extent. A plate of iron, with several copper rivets in it, was placed in the boiler (at the same time as the zinc), and a somewhat similar plate in another boiler working at the same pressure. There appeared to be no action in either case. The zinc in the Rhes Las boiler formed a galvanic circle with the iron, and protected, in some measure, the action taking place on the iron with the copper rivets.

In 1854 a new boiler was placed by the side of the old one, the same water being used (the author was under the impression that other water had been procured for the new boiler, until his attention was called to it at the commencement of the present year). A similar action is going on in the new boiler, although the plates, instead of being eaten into holes, are eaten away more smoothly, especially at the joints and about the rivets, where large scales of oxide of iron may be found: some of the scales, mixed with small particles of metallic copper, are exhibited.

Pieces from the highest parts of the plate exhibited (from old boiler) were found to contain copper, being protected by its influence, and the surrounding iron being eaten away. A similar action is taking place in a boiler about two miles distant from the Rhes Las, where the water is of a similar character. The best method of preventing the action of this water on the boiler, the author has not had sufficient practical experience to pronounce decidedly on. The first point necessary would be to scale the iron to some extent with a compound of lime, so as to prevent the action of the copper salt. Probably lime, chalk, or even limestone might be used with advantage. As the experiments must necessarily be extended over some time, the author has not been able to form a decided opinion, but trusts at some future time to communicate to the society on the subject.

DISCUSSION.

The CHAIRMAN asked if Mr. Riley attributed the corrosion of the plates of the boiler solely to the action of copper. In Cornwall he understood no such result had been found, although there could be little doubt that the water used often contained copper.

Mr. Riley considered that the presence of copper was quite sufficient to account for the action on the boiler. He was sorry to say he had not been successful in obtaining special information from Cornwall on the subject, although in a communicatian from Mr. Warrington Smyth, of the Museum of Geology, he says that "boilers are acted on, but he is not aware of any case where metallic copper has been found in them." The Dowlais boiler-maker, a Cornishman, had never seen a boiler acted on in a similar manner. He (Mr. Riley) was of opinion that there might be cases where mineral water, containing copper, would not act on a boiler; for example, water holding much lime in solution, which, by boiling, would be precipitated and prevent the deposition of the copper on the iron, and a galvanic circuit being formed. In the plate exhibited, the raised portions were found to contain copper, which accounted for their not having been eaten away. Instances of the effect of a minute portion of another metal or body acting positively were numerous. For example: the tube exhibited contained a piece of cast iron in sea water hermetically sealed *in vacuo:* after the lapse of a few days the water became green, and soon after a deposit of protoxide of iron was apparent. Again: a leaden rose on an iron steam pipe quickly eats it away; and Sir Humphrey Davy's plan of protecting copper sheathing of ships by the introduction of zinc bars, where the action was so perfect that the copper became incrusted with barnacles and other mollusca, to the impeding of the ship's progress, the zinc, of course, being dissolved. It was not unusual to find the same metal existing in an uneqnal state of oxidation, forming a weak galvanic circle.

Mr. Rogers said engineers had not attended sufficiently to the effect of the action of oxides upon metals. He thought Mr. Riley's theory correct, and had himself no doubt that the corrosion of the plates of the boiler was due to galvanic action.

Mr. Roper gave a similar opinion.

Mr. Cox mentioned an instance which, he said, although differing from the point under discussion,—inasmuch as it occurred with cold water instead of hot,—still showed that the action on metals by substances held in solution by water was sometimes very great, although existing therein in quantities infinitessimally small. He knew a case where the copper balls, of ball cocks supplying cisterns, through each of which ten tons of water passed per day, were invariably destroyed in about six weeks by the action of the water into which two or three pounds per day of a very pure coke was allowed to fall, while ball cocks to other cisterns, supplied by the same pump had remained sound for seven years, thus establishing the fact that their destruction was due to the presence of the coke, and, he imagined, to the sulphate of iron which it contained.

The following paper was then read:—

ON THE

EFFECT OF MOMENTUM ON PUMPING MACHINES.

By Mr. R. HENRY MICHELL, of Cardiff.

In a mining locality, such as the one in which we are situated, the action, character, and importance of our pumping machinery are well known and appreciated, therefore anything illustrative of, or tending to throw additional light, however small, upon this subject, will doubtless be interesting.

The extensive mining operations of this country have produced exigencies that have taxed the talents of engineers for centuries, and to those exigencies and necessities, may be traced the mechanical parentage of such men as Watt, Trevithick, and a hundred others, whose names connected with this subject will never be forgotten.

Mining, while it is confined to, or near the surface, is a very simple operation; a small amount of geological knowledge in the shape of experience teaches the miner "to know tin." He digs away, and usually profits by his labour, the deeper he gets the more he is encouraged, for in all probability his "lode" gets richer, but at length he is stopped by that most insidious enemy to mining, water. In order to relieve his position he goes to the lowest valley near, drives a level under his mine, and drains it. But his lode tempts him below this level; he then gets a horse whim, but this does not help him much, and he is obliged to apply to the engineer, who assists him, if the locality be favourable, with a water

wheel and pumps. He thus proves his mine to a certain depth; still he finds he wants to go deeper, and must have more power, and now the talents of the engineer are called into play. It was a great thing to get a steam engine constructed to work on a mine at all for pumping purposes, but that has become a fact accomplished, and the machine has been from time to time improved upon, until the power and efficiency of the pumping machines on the mines of Great Britain are unequalled. Notwithstanding, the question still is how to get the best form of engine and pumping apparatus to work with the greatest economy, for the minerals are only worth a certain value, and in a deep mine the expense of getting at them must be reduced as much as possible or the "Bal must knock."

In Cornwall especially, the value of this economy in getting the greatest amount of work performed at the least cost, has been seen and appreciated, especially during the last half century. About the commencement of the period alluded to, engineers began to find that high steam, worked expansively, produced a great increase of duty.

Expansive steam was immediately supposed to be capable of working wonders. Cylinders were made longer, steam was cut off at one sixth of the stroke, perhaps in some instances much earlier, and the success was most flattering, the duty performed in some cases exceeding an hundred millions. Thus the single acting pumping engine became, in the hands of the Cornish engineer, pre-eminently the best, cheapest, and most effectual pumping machine.

But the results of the last fifty years experience prove that the success of the Cornish engineer was due more to the peculiar circumstances with which he had to deal than to his genius; for it does not appear that he knew where his strength lay. For instance, in deep mines, of necessity the pump rods must be long, and in order to be strong enough, are of more than sufficient weight to counterbalance the column of water, therefore there was no necessity for steam on the piston one way, except to act as a check; the engine would go of itself, and it would go too fast, hence the necessity of "balance

bobs," which he has been so desirous to do away with, but which in reality have been the secret of his success.

Again, in a progressive mine, when a new engine was erected, it was generally of greater power than was necessary for the then state of the mine, being calculated to meet future requirements as the mine deepened. This circumstance gave the engineer an opportunity of experimenting with a superabundance of power, and he found that by using the steam at the same pressure as he was obliged to do with his old engine (that was then only just capable of moving with its load), his new engine would do the same work with the cylinder only partly filled with steam, and that he saved a great quantity of coals. This difference was immediately and wholly attributed to the expansive power of steam, and acting upon this false datum, he was led into endless errors. The cylinders of the winding and stamping engines were lengthened until they were as long, and the steam cut off as short as the pumping engines, but in these cases the expansive principle was never found to be as effective as in the pumpiug engine. Cylinders were made double and the steam re-expanded, but the duty not increased thereby.

At length it became generally acknowledged that the same useful effect could not be produced with the same quantity of coals, by engines used for giving motion to machinery, as by the pumping engine.

The Cornish engine was then transplanted to London, fitted up in the very best style, and the greatest care taken of it; its water warmed, and the temperature thereof noted; its friction carefully weighed, for it was to be relieved of that incubus of extra weight that the mine engine of necessity is obliged to move and have only one lift of pumps! Therefore its excess of duty was expected to be something considerable, but it never exceeded the duty of the old mine engine, with all its friction, arising from depth of shaft, number of lifts, "balance bobs," &c.

If this be the result of experience, and a fair statement of the state of things, where are we to look for the cause of this discrepancy? Why does not the winding engine, or any other en-

gine giving motion to machinery and controlled by a fly wheel, although working equally expansive, compete in duty with the hard-worked pumping engine? Why does not the strong young London engine, with its friction reduced to a nominal quarter of a pound per square inch on the piston, exceed the duty of its old parent, labouring under the disadvantages of weight and poverty at the Land's End? Is there any item left out of the calculation, in estimating the relative capabilities of the various engines? Undoubtedly there is! And the necessary item is the momentum produced in the ponderous mass, by the excess of power used during the first part of the stroke, causing a greater velocity to be imparted than would have been the case, had steam only equal to the load been used throughout the whole stroke: therefore the velocity and the mass should be considered.

Taking the average of Cornish engines, there is a great uniformity in making the indoor stroke, for the sudden shock given to the machine in order to start the whole load from a state of rest, and to give it a velocity of about six feet per second, is necessarily great; therefore the engines are invariably made strong, and the capabilities of the machine to withstand this shock with ease and steadiness, determines the strength of steam with which the load shall be started, and the portion of the stroke at which it shall be cut off, the object of the engineer being to work expansively as much as possible. Thus an engine working only two strokes per minute, makes the indoor stroke with nearly the same velocity as if it were working ten or twelve strokes per minute.

Another equally important item, in order to ascertain the comparative efficiency of the Cornish Pumping Engine, is the weight of the matter in motion, and more particularly the weight of that part of it that is balanced off. The whole of this matter is put into an equal state of velocity. The mass constituting the legitimate load, (that is a weight equal to the column of water raised, with the extra weight necessary to give sufficient strength and rigidity to the rods), has its velocity given to it, contrary to the laws of gravitation, therefore its momeutum is soon arrested. But the mass, constituting the balance of the extra load, has its velocity

given in the direction it would gravitate, therefore, its momentum accelerates throughout the whole length of the stroke, and although the extra weight and its balance are equal, yet in a state of motion they do not balance each other, but act under, and serve to illustrate, two well-known laws in physics. First, If a force be expended to put a body in motion, an equal force will be required to destroy that motion; and Secondly, That the mass of the body multiplied by the velocity of its motion, constitutes the mechanical effect of its momentum, or its quantity of motion. It is evident then, that the greater the weight in the shape of balance, the greater will be the effect of its momentum, provided its velocity be maintained.

How, then, can the comparative efficiency of any number of Cornish Engines be justly estimated, when these items are left out of the calculation? And to prove that they are left out, let reference be made to Mr. Lean's Report of Cornish Engines, and Mr. Wickstead's Experimental Inquiry concerning the relative power, and useful effect produced by the Cornish and Boulton and Watt Pumping Engines. In Mr. Thomas Lean's Report we are informed of the situation of the main beam, when there are one or more "balance bobs," and if they are situated at the surface, or underground; also if there are "angle bobs," or "flat rods", and how many; and also if any part of the rods are diagonal, and what parts are perpendicular; but all this is in order that a judgement may be formed of the friction the machine has to overcome. In no instance are we informed of the weights balanced off by those "bobs."

In one of those Reports for March, 1856, two Engines at East Wheal Rose Mine, Penrose's and Michell's, are reported both equal in every respect, 85 inch cylinders, 10 feet stroke in the cylinders, and 9 feet in the pumps, and both making 4.2 strokes per minute, while the character of the pump-work was very similar. But Penrose's, with 14.6lbs. per square inch load on the piston, and 30lbs. of steam in the boiler, was reported to have done 52.3 millions, or to equal 105 horse-power, while Michell's, with 12.7lbs. load on the piston, and 33lbs. in the boiler, is reported to have done 49.2 millions, and therefore equal only to 91 horse-power.

This is not a solitary case, but it is a very remarkable illustration of the want of the total weight of matter in motion being brought into the calculation, for there can be no question that if 10 tons had been added to the rods of Michell's Engine in this case, and balanced off, without making any allowance for the friction it would occasion, or without altering any other item in the calculation, this engine would have exceeded the duty of the other, and have been reported at 120 horse-power. And for this reason: the same pressure of steam on the piston would produce a velocity, if not equal, not sufficiently diminished (by friction or augmented mass to put into motion) to deter it from travelling a greater distance than it did before, in consequence of the momentum due to the increased mass; or, in common parlance, the engine would work more expansively. But it must be clearly understood, it would be only those engines that possess a sufficient excess of power to produce the necessary velocity, that could be beneficially experimented upon, for when the load begins to equal the power of the engine, any additional weight would have the contrary effect, because of the decrease in the velocity; and this may be carried out to the full extreme, by supposing the engine to be constantly approaching a state in which the load should be exactly equal to the power, when it would be a balance on an equal beam, having neither velocity nor momentum.

But if a part of the stroke, either more or less, be performed by the momentum, does it not, at the same time, appear self-evident that the indicated diagram of the expansion of steam, in the Cornish Engine, is of a very delusive character. The Cornish Engine has been generally quoted as a notable example of the expansive power of steam, and Mr. Wickstead, in his preface says, that "Cornish Engineers have carried out the system of working steam expansively much further than any other Engineers, and great credit is due to them for the skill they have displayed."

Now, the writer is of opinion that the useful effect due to the expansion of steam is exactly as much in the Cornish engine as any other engine, and no more. Is it reasonable, because the natural conditions under which the engine works, are peculiarly

adapted to exhibit the effect of momentum, being an attached mass free to move independently of the fluid, and moving in the direction of the impetus given to it—because an impulsive force is given during the first sixth-part of the stroke, that produces a momentum in the mass capable of performing another sixth-part of the stroke even if the whole steam could be suddenly destroyed, that the whole result should be given to the expansive power of the steam? Surely not! But the fact is, that the expanding steam accellerates the motion with all the effect due to its expansion in any other vessel, and the two forces combined complete the stroke.

In the 34th page of Mr. Wickstead's pamphlet, he seems to have some misgivings on this subject; there was something puzzling,—something in the calculation of the duty of his engine compared with the Cornish engine (Taylor's, at United Mines),—that he could not understand, for he says, "It is evident that it has more machinery to work than the one experimented upon by me, and therefore unless worked more expansively, or the coals used were of a superior quality, it could not have done the same duty, because it must be borne in mind constantly, that be the number of pumps ever so numerous, the distance from one pump to another ever so great, still the Cornish 'duty' includes the friction arising therefrom." What does Mr. Wickstead mean by the engine moving the greatest weight, working most expansively?

And again, on the 33rd page, "It is very certain that the Cornish engine experimented upon ought to have done more duty than any engine in use for mining purposes, because the friction is less, or, in other words, there is less machinery to move to lift the same quantity of water."

If the whole effect were to be produced by the expansion of the steam, the engine Mr. Wickstead experimented upon not only ought to have done, but would actually have done more duty than the engines used for mining purposes,—so that here the same error is exemplified.

Mr. Wickstead says his engine ought to have exceeded in duty,

because there was less machinery to move. Supposing he had divested his engine of its heavy beam, aud placed the cylinder upside down on the top of the pole to lift direct, there could be no objection to such an arrangement, as there would be still less machinery to move; the duty, however, would have been reduced. Carry the supposition still further,—do away with the weighted plunger altogether, and let the inverted cylinder work, drawing lifts equal to the load, the weight of the machinery to move would be much reduced, but the duty would be still further diminished, because the motion would require to be much more regular, as there would be no mass attached to the engine, which therefore would work less expansively by one half.

It would appear, therefore, that in addition to the actual load of water, and a description of the circumstances whereby to judge of the friction, that the total weight of the mass moved, and the velocity with which it is moved, are necessary items to be taken into consideration in calculating the comparative or competitive qualities of Cornish pumping engines, in order to reconcile the otherwise incomprehensible discrepancies. When this is carried into effect, and experience proves that the engine moving the greater mass (taking the water load and the velocity to be equal) is the one that performs the highest duty, the effect of momentum, as an item of calculation in estimating the duty of the Cornish engine, will be established, and the indicated diagram of that engine will never again be represented as an example of the expansive power of steam.

Double engines are used in a great many instances for the purpose of pumping, but they come under the same class as all others used for moving machinery, &c., as in such cases the engine is supplied with a crank and fly wheel, for the purposes of turning the centre and controlling the motion.

On a small scale such engines may be used with advantage, as they save room and first cost, but large engines of this kind can never work economically, for the momentum of the fly-wheel, which has the effect of regulating the engine so beautifully when giving motion to machinery, is actually injurious when the engine

is applied to pumping, because it comes into periodical contact with the momentum given to the fluid, thereby producing a series of shocks in the pumps.

The next part of this paper is intended to notice the effect of momentum on fluids, while under the action of pumping.

Fluids, like solids, are acted upon by the laws of gravitation. These laws govern the action of the fluid under circumstances varied without end, and as the results of the action may not be the same under cases where the difference of circumstances is scarcely appreciable, the engineer must follow his investigations into each particular case in detail, and, by practical experiment, endeavour to obtain a knowledge of that which is taking place out of sight, inside of pipes, affected by air pressures, velocities, curves, and friction.

The plunger pump may be taken and followed throughout its entire stroke. During the first part it produces a vacuum between the plunger and the valve, equal to the weight of the valve; the valve is then lifted by the pressure of the atmosphere, and by the same pressure the water is driven after the plunger, to fill the otherwise empty space. Thus the up stroke is completed, and the working barrel filled, with the exception of so much as the weight of the valve counteracted, but as the up stroke is made quickly, a velocity is given to the column under the bottom valve, which imparts a momentum to it, and this expends itself in sustaining the weight of the valve until the working barrel is completely full, and it may not then be quite expended, but continue to act, and if the valve be too light, and the engine working quickly, this force may keep the valve from regaining its seat so long as to allow the engine to return its stroke, and bring the valve on its beat with the whole weight of the load, making what is termed the "valve to beat hard."

This becomes a very serious matter sometimes in large pump work, especially if the suction is long. Instances have occurred of large suction pipes having been broken off immediately under the valve, by the power required to check the velocity of the column

of water, when the pumps have been worked by engines having a fly wheel.

The remedy generally applied, in very bad cases, is to place a vacuum vessel near the valve, into which the water is diverted, while the plunger is on the centre.

In Cornish pumping engines this state of things is prevented by having little or no length of column under the valve, that is, in ordinary cases; but the writer has seen a large pump, put into such a sudden state of velocity, by a short stroke of high steam, as to leave the water behind for two or three feet of the stroke, when the sudden rush of water under the plunger appeared to relieve the engine, and it would start off afresh, with a tremendous jerk, to perform the remainder of the stroke. This circumstance occurred by the velocity given to the plunger, producing a large amount of vacuous space, in less time than the inertia of the water could be overcome, by the pressure of the atmosphere.

Now notice the plunger during its descent. As soon as the plunger moves, the valve lifts, and motion is communicated to the ascending column, which is accelerated as the plunger proceeds, and when the stroke is finished, provided the ascending pipes are the same diameter as the plunger, the velocity of the ascending column is the same as that with which the plunger descended; or, if not, is more or less in proportion to their areas, and a momentum is given to the ascending column, dependant, as to its force, on that velocity.

If the column be moved slowly, its momentum may not oe appreciable, but in cases where engines are working quickly, it is considerable, and to expend its effect, the whole column of water passes on in advance of the valve. Then if the area of delivery in the valve be too small, so as to occasion too great a lift, or if the valve be too light, so as not to regain its seat before the reaction takes place, the weight of the column returns, and brings the valve on to its seat with a force which occasions, in this case again, the "hard beating of the valve."

In the Cornish engine, where the pump work is proportionately

small in area, the evil effects of this are not so severely felt, as in the case of the London pumping engine, where the circumstances are exaggerated.

The first large pumping engine erected in London, at the East London Water Works, at Old Ford, had a single lift of pumps equal to the whole load, and was supplied with valves very similar to those commonly used in Cornwall, known as clack, or single beat valves. The concussion, owing to the reaction on these valves was so great, that they had to be thrown out, and superseded by Harvey and West's double beat valves. Those, having a greater area of water way in consequence of having two beats, let the water through with less lift, and having only the annular ring between the two beats for lifting area, opposed much less surface to the passage of the current; besides, the weight was so much greater (the weight of those valves, compared with the lifting area, being equal to 1.9lbs ℔ square inch). So that all these circumstances together, gave the valve an opportunity to regain its beat quickly, and it worked so quietly, that it could scarcely be heard; while the column of water reacted upon the previous ones, with such force as to shake the whole engine and house.

In large pumps, such as have been referred to, when the engines are working quickly, the momentum given to the ascending column (occasioning it to pass on in advance of the valve, and the consequent reaction) is not a matter to be judged of only by the hard beating of the valve. It is not a question of inches merely, but is one of feet.

The writer has seen the water undulate from three to four feet at every stroke of the engine, while standing on the top of a column 170 feet high and four feet in diameter. That is, the water came up and passed out at the overflow, then immediately receded three or four feet below the outlet of the overflow, although the column was a foot larger in diameter than the plunger. The idea which this circumstance presented to his mind was, that there must have been a vacuum produced under the column, and a very short time afterwards an opportunity occurred of proving such to be the fact, by observing a leaky joint immediately over a delivery valve, where

there was a pressure of fifteen to twenty feet over the valve. The instant the stroke of the engine was completed, the leak drew in air with great force, and, after a short interval, the water came out with equal force, and continued to flow until the next stroke was completed; proving, in both instances, that the effect of the momentum was considerable, and the loss of power consequently very great. For, it must be apparent, that if a power be applied which produces a certain amount of velocity in a column of water, and that velocity is allowed to expend itself, stop, and react, there must be loss of power.

Air vessels are often placed near the delivery valve, with a view to remedy those defects, but they simply relieve the valves by acting as cushions, and even then the air must be maintained in them by pumping, or the water will carry off all the air with it, and so render the vessel useless.

With a view to investigate this subject yet further, and to obtain, by experiment, positive information, an arrangement of pumping apparatus, represented in the accompanying drawing (see plate No. 10,) was invented by the writer, and a working model, with four inch plungers, constructed. The object being to allow both the suction and ascending columns an opportunity of expending any velocity obtained, without check, and thereby to do away with the evil of reaction.

This object is attained by connecting the suction pipe and the delivery, by making a continuous pipe from one to the other, and separating them only by placing a valve between.

The results obtained from repeated experiments were, that the pump delivered more water than was due to the displacement of the plungers.

The faster it worked the more it delivered; and when worked at the rate of 100 feet per minute, it delivered from 48 to 50 gallons per minute more than the contents of the plungers.

As far as the column under the valves was concerned the experiment was extremely interesting, because the action of the valve

could be seen, and the quantity of water separately measured. By taking off the valve door A, and placing a plug in the pipe B, above the valve, the valve could be seen lifting every time the plungers turned centres, and the water would flow out of the doorway. When the pump was worked quickly, the water that came through this valve equalled one-third of that delivered by the plungers.

DISCUSSION.

Mr. Pearce said that he had experienced considerable difficulty with some pumping machinery formerly under his management. Owing to the small diameter and great length of the discharge pipe, which stood at an inclination of about 1 in 12, the velocity of the column was so great that was carried onward by its momentum, after the working stroke had finished, leaving thereby a partial vacuum above the delivery valve, as explained by Mr. Michell. To remedy this defect, he tried air vessels in various positions, without success. The evil was at last cured by erecting a stand-pipe. He promised to give, on some future occasion, the particulars of this pump, and the head of water required in the stand-pipe, to overcome the friction of the delivery-pipe.

Mr. Criswick thought Mr. Michell's plan an ingenious one, but did not think it extensively applicable. It was not required in the ordinary Cornish pump, which, in his opinion, was the best suited for raising water.

Mr. E. Rogers understood Mr. Michell that he did not intend to put his plan in competition with the Cornish pumping engine, which was constructed to take the greatest advantage of the expansive power of steam. In some cases the steam was cut off as early as 1-16th of the stroke. He thought Mr. Michell's plan very ingenious, and had no doubt it would be found useful under certain conditions.

Mr. Roe thought the single-acting Cornish engine a very perfect machine, and better suited than any other for pumping. A large amount of inventive skill had been expended in bringing the machine to its present state of efficiency. It is true that the double-acting pumping engine, with a fly-wheel attached, presents admirable contrivances for diminishing the concussion of the pump valves, and of relieving the pipes and rods from sudden and unequal strains. Yet it does not, in practice, afford equal facilities with the single-acting engine, for working at low rates of "speed," a matter of considerable importance in sinking operations, and in new winnings, before the workings become extended, and the quantity of water proportionally increased. It is also a generally received opinion amongst engineers, that the expansive work-

ing of steam cannot, with equal economy, be carried to so great an extent as in the single-acting engine.

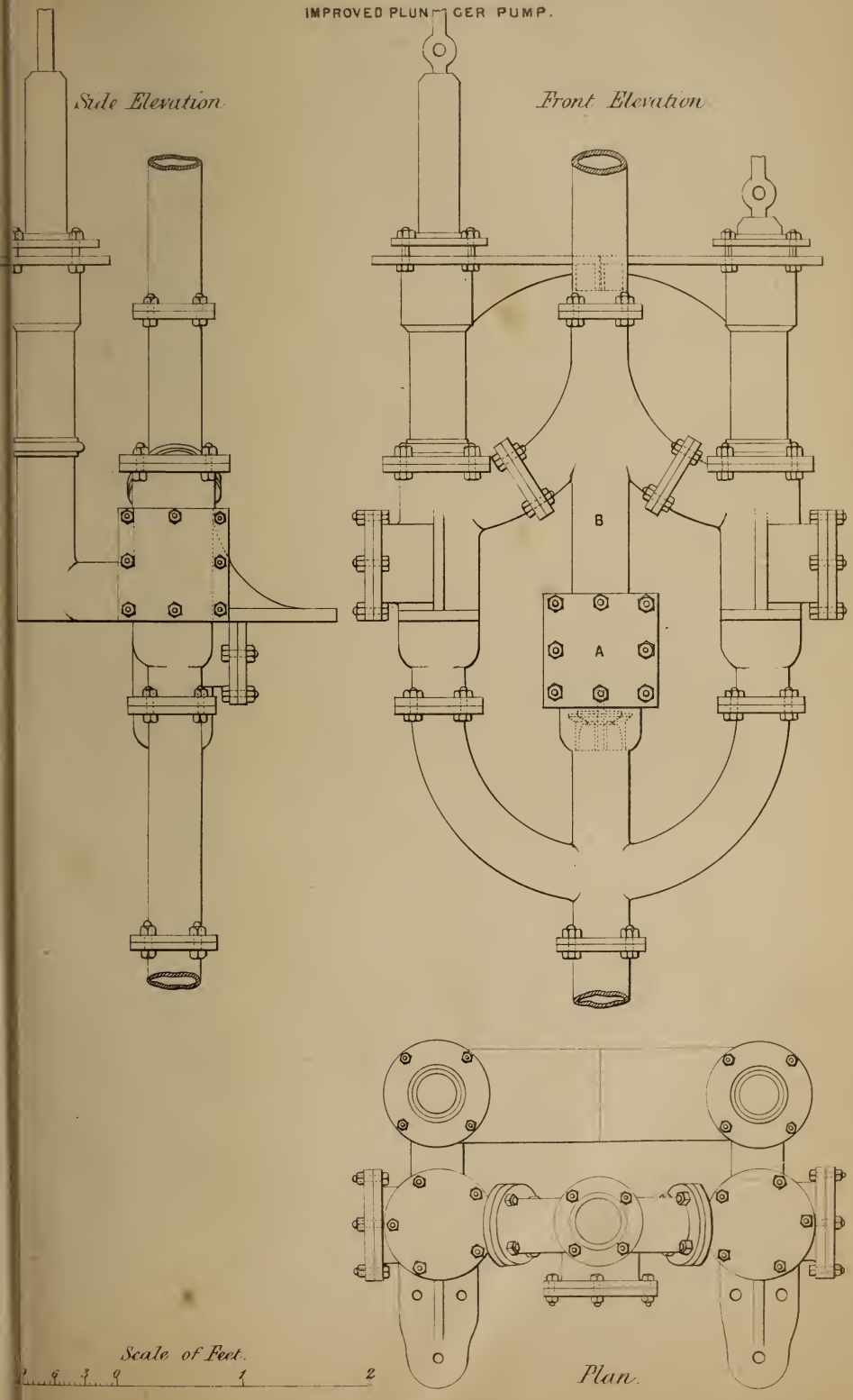
The PRESIDENT presumed that Mr. Michell only intended to recommend his improvement in cases where pumps were badly proportioned, and, of necessity, driven at high speeds. He thought Mr. Michell had been somewhat hard on Cornish engineers, in attributing their great success to the mere chance of their having a machine peculiarly suited to the application of the expansive principle. He thought a great amount of ingenuity and inventive skill had been brought to bear upon the Cornish pumping engine. No doubt it was well suited for using steam expansively, but he thought Cornish engineers deserving of great credit for having made the pumping engine one of the most perfect and economical machines in existence.

Mr. MICHELL had no wish for a moment to detract from the ingenuity and skill that had been exercised by the Cornish engineers, but nevertheless adhered to his opinion, that the economy of the Cornish pumping engine was due to the velocity with which a great mass of material was moved by a short stroke of steam, and that that part of the effect which was due *only* to the momentum of the mass, should not be attributed to the expansion of the steam. The application of expansive steam had not been attended with the same success in rotatory engines. As regards the application of his improvement, he thought it was well adapted for ships, or other pumps, worked at a high speed. By simply fastening a piece of India rubber tubing to the discharge pipe, and passing it overboard, it is formed into a regular syphon, and the labour of pumping is reduced to the weight of a column equal only to the actual difference of the level of the water inside and outside the vessel.

The PRESIDENT proposed a vote of thanks to Mr. Michell, for his very interesting paper, which was carried unanimously.

PUMPING MACHINERY.

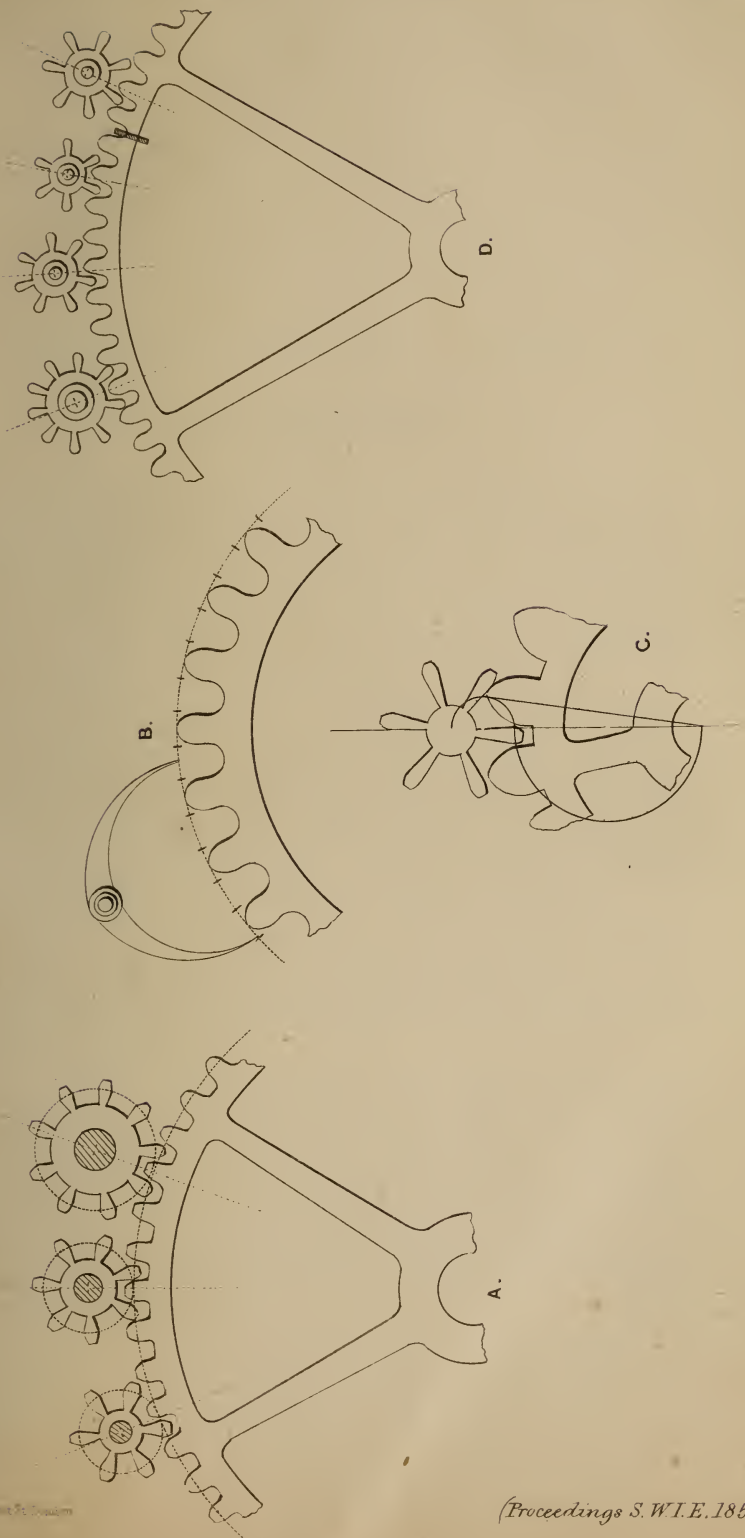
IMPROVED PLUNGER PUMP.



(Proceedings S.W.I.E. 1858.)

Matchum & Burt, 20 Parliament

TURRET CLOCKS.



Court of Exchequer Syndicate

(Proceedings S. W. I. E. 1858.)

ON MAKING TURRET CLOCKS.

By Mr. COPE PEARCE.

Being only an amateur in this art, it is not my intention to treat of horology in its higher branches, as I am not equal to that task; but I can give sufficient information on the subject, to enable an Engineer, at an Iron Works, with the means usually at his disposal, to construct a good sound turret-clock, sufficiently accurate for all practical purposes, and at a moderate cost.

I will not waste your time by going into the disputes of who was the original inventor of clocks with wheels and weights, but only mention that in the year 992, Archbishop Gerbert made something like the going part of a clock, actuated by wheels and weights, which was considered so wonderful in those days, that it was supposed to have been invented by the aid of the devil.

The next clock worth taking notice of is a turret-clock, with a striking part and crown-wheel escapement, made by Henry Vick, who went over from Germany, and erected the same at Paris, in the year 1370, for Charles V.

The escapement worked a balance, backwards and forwards, like a common bottle-jack, and the time of vibration was regulated by moveable weights, fixed on the arms of the balance. This clock is remarkable for having a locking plate, for regulating the number of blows struck by the hammer, which piece of mechanism, for a large clock, has not been much improved since, and will probably never be superseded.

The next improvement of consequence, was the application of a pendulum to clocks, which is supposod to have been first done by Richard Harris, of London, who made a pendulum clock for St. Paul's Church, Covent Garden, in the year 1641. Huygens, who also claims this invention, discovered some curious properties in a pendulum vibrating in the arc of a cycloid, which I shall have occasion to mention again.

The ratio between the length of a pendulum, and its time of vibration, was first made known by Galileo, in the year 1639. About the year 1666 Dr. Hook invented the "Anchor Pallets," which are still used in common clocks; and this was a very decided improvement over the old crown-wheel escapement, till then in use.

Having detained you as little as possible with the history of clocks, I shall go on to the actual making of them, which will be more interesting to practical men.

First of all, I believe that cast iron is a better material for large clock wheels than brass, with the exception ef the escapement-wheel, which must be brass. Iron wheels, with the teeth cast, have a hard skin, which gets glazed from working with steel pinions, and seems likely to go without wearing into steps for a length of time. Brass wheels, in a few years, wear into these steps or gums, and some times give a great deal of trouble; for as wheels and pinions are never in reality quite true, it follows that these gums get worn to different depths from this eccentricity of the wheels, and the consequence is, that when the clock is taken down to be cleaned, if the wheels are not put back again tooth to tooth, exactly as they were before, the end of a long tooth will perhaps have to work in a space with a shallow gum, which will evidently butt against this long tooth, and stop the clock. In many old churches, iron clocks are to be seen, which have been working at least two hundred years, without the wheels being worn or rusted to any extent, so we may safely use iron for any clock we are likely to make.

There is no difficulty in casting wheels 7-16ths pitch, which will be found quite fine enough for any part of a large turret clock, and they can be cast sufficiently true, as the time-keeping of a clock does not depend so much on the truth of its wheels, as on

certain adjustments, which I shall presently point out. The breadth for the wheels at the lower part of the clock (where the greatest strain comes) can be made about twice the length of the tooth, and the strength required will be found, thus:—Divide the square root of the strain in pounds by 40, and the quotient is the thickness of the tooth, in parts of an inch.

The upper wheels have very little strain on them, so they should be made much narrower, to reduce their weight as much as possible. To drive a large clock, it will be necessary to have large weights, but a man can only wind, with a force of thirty or forty pounds, on a winch handle of 17 inches radius, so it is necessary either to make the diameter of the barrel very small, or apply a pair of spur wheels like a crane, to increase his purchase. The small barrel plan is generally adopted, but I prefer barrels of larger diameter, with crane wheels, for the following reasons:—Small barrels wear out the rope sooner than large ones; they require to be made so long, to enable them to hold rope enough, that they cannot be put in the same frame as the rest of the clock, but must have a frame to themselves outside. The rope is also liable to ride with one lap over the other, unless there is a great distance between the barrel and leading block, which cannot always be obtained in a clock tower. In small turret clocks, a barrel with 30 coils of half-inch rope can be made short enough to go into the clock frame, but with inch rope, making forty or fifty coils on a barrel, the case is different.

Some modern clock-makers overcome this difficulty of length, by using small wire rope; and in what are called "three wheel trains" the increased number of turns a small barrel is obliged to make in running off a given quantity of rope, is an advantage, but for "four wheel trains," the best plan is to make the barrel long enough to take in 16 coils of rope, and the diameter as large as the fall or length of the tower will admit of. You will understand these remarks about barrels better after I have explained the number of teeth used in clock trains, which I will do after saying a few words on the action of wheels and pinions.

If the wheels in clocks bore as low a ratio to the pinions, as

they usually do in mill work, the gearing would be like machinery, on a reduced scale, and it would be unnecessary for me to make any observations on this part of the subject to mechanical Engineers, but in clock trains a great disproportion between the wheels and pinions is often required, and pinions with only a few teeth must be used, in order to prevent the pitch being too fine, in a wheel of moderate diameter.

Now supposing an Engineer or Millwright to set about a wheel and pinion for a clock, he would very naturally strike out pitch lines, and make something like what is represented at Plate A, but this would not work well for pinions below ten teeth, owing to the teeth beginning to act too far before the line of centres, so we must adopt another plan.

Camus has demonstrated that a wheel cannot uniformly move pinions of seven, eight, or even nine teeth, by only driving their leaves after the line of centres, and, of course, pinions of six and five are worse. However, in practice we can bring the action so near the line of centres that no inconvenience is felt. When the wheel drives the pinion, this is done by putting the wheels very deep in gear, and making the pinion very small, which has the effect of making the wheel tooth carry the leaf of the pinion further backwards than it would otherwise do. This is called giving "drop" to the teeth, from the circumstance of one tooth slipping off, a little before the other engages, and this drop can be so regulated and reduced by properly sizing the pinion, that it is almost imperceptible. In case the pinion drives, the wheel must be shallow in gear, and the pinion very large.

Plate C shows a wheel and pinion formed according to theory, with epicycloidal curves, described by rolling one circle of half the diameter of the pinion over another of the same diameter as the wheel, which has the effect of making the point of contact of the teeth always coincide with the semicircles shown on the plan, in which case Camus has proved that the force transmitted from the wheel to the pinion, will be a constant quantity. Now a practical man will see at once, that although these teeth are better for the purpose than those at Plate A, still the teeth come in contact too

soon, and it will be found beneficial to put the wheel deeper in gear, so as to give a certain amount of drop, which will of course waste force, but not so much as the friction of the teeth would do, if allowed to act too far from the line of centres.

If you want to be very scientific about the curves, you must roll them as above described, but it is not necessary in practice, for you can imitate the true curve of wheel teeth sufficiently, by rounding the point off with a radius of two thirds of the thickness, as shown at Plate B, which is the shape commonly employed. With regard to the pinion teeth, it will be found quite near enough to round off their points into semicircles, as the length of curve in action is very short, and I may observe, that the thinner the pinion teeth are made, if driven, the better the action will be, but quite the reverse if the pinion drives the wheel.

The best rule for the distance between the centres of a wheel and pinion, so as to put them the proper depth in gear, is this:—

When the wheel Drives $\left|\dfrac{(\text{No. of wheel} + \text{No. of pinion}) \times \text{diam. of wheel over}}{2\ \text{No. of wheel} + 4.5}\right| = \text{Dis.}$

When the pinion Drives $\left|\dfrac{(\text{No. of wheel} + \text{No. of pinion}) \times \text{diam. of wheel over}}{2\ \text{No. of wheel} + 3}\right| = \text{Dis.}$

Or in words,—

Multiply the number of teeth in the wheel, added to the number of teeth in the pinion, by the diameter of the wheel over the points of the teeth; then, if the wheel drives, divide the product by 4·5 added to twice the number of teeth in the wheel, and this gives the distance between the centres. When the pinion drives, divide the product as before by 3, added to twice the number of wheel teeth for the distance required.

The proportion for a pinion has generally been given thus:—

As the number of wheel teeth driving + 2·25, is to the diameter of wheel over, so is the number of teeth in the pinion + 1·5 to its diameter over, and when the pinion drives, the constant numbers must be reversed. As far as my experience goes, this rule makes the pinions too large, and I think the plan of measuring the pinions by spaces on the wheel itself much to be preferred. A very con-

venient rule for the purpose is this,—Multiply the number of pinion teeth required by 2, then add 1, and divide by 3, which gives the number of spaces and parts. This can be taken by means of a pair of callipers, so as to guage the diameter of the pinion in the lathe, to the greatest nicety. In case the pinion drives, you must add 2·5 instead of 1, in the above rule. At Plate B, you will see the distance measured for a driven pinion of 8, thus 8 × 2 is 16, and 16 + 1 is 17, then 17 divided by 3 is 5·66, or 5 spaces and two-thirds of the next, for the diameter of pinion. If the pinion was the driver, the diameter would be 8 × 2 is 16, and $\frac{16 + 2{\cdot}5}{3}$ makes 6·16, or full 6 spaces. This method is much in use among clockmakers, who generally learn by rote how many spaces and parts to take for a pinion, and they come very near the mark without any calculation.

We now come to the number of teeth used in clocktrains, and I need not tell you that many ratios can be represented correctly by only one wheel and pinion, but in clocks the ratio is too high, and must be represented by several wheels, as there is a limit to the number of teeth, that can in reality be put on a wheel. For instance, if we want 120 to 1 with a pinion of eight, the wheel would be 960, which would be quite out of the question.

Perhaps before we go any further it would be well to remind you, that the clearest way to express the ratio of wheels on paper, is to write them like a fraction, and in clock-work it will prevent much confusion, if you always make the driving wheels the denominator, and the pinions driven the numerator.

Now the ratio 120 : 1 is the fraction $\frac{1}{120}$, or what is the same thing, $\frac{1}{12} \times \frac{1}{10}$; so if we multiply by the pinion of 8, we get the train $\frac{8}{96} \times \frac{8}{80}$, which will do very well. If we divided the fraction into $\frac{1}{8} \times \frac{1}{15}$, and formed a train of $\frac{8}{64} \times \frac{8}{120}$, it would be the same thing in theory, but more teeth would be required, the number amounting to 200, whereas in the former train the sum of all the teeth is only 192. The above example is easy, because you can guess at once what numbers will divide the denominator. But this is not often the case, and a common slide-rule will be found very

useful for this purpose, as it shows all these numbers at once, by inverting the slide, thus:—

Set 1 on A.	1	1·2	1·5	2	2·4	3	4	5	6	7·5	8	10	
to	×	×	×	×	×	×	×	×	×	×	×	×	
120 on ☉,	120	100	80	60	50	40	30	24	20	16	15	12	and so on.

When the train consists of more than two wheels and two pinions, the above method is not convenient, and the following rule wll be found best:—Multiply the given number by the product of all the pinions, and divide out by the prime numbers, beginning at 2, then 3, then 5, 7, 11, 13, 17, and so on till nothing remains, then the prime numbers which have been used will form a series of numbers which can be multiplied by each other, in any order you may think fit. If we try the same fraction as before $\frac{1}{120}$, by this rule with three pinions of 7, 8, and 9, the process will be thus,—

$7 \times 8 \times 9 \times 120$ gives the number 60480.

Then,

2	60480
2	30240
2	15120
2	7560
2	3780
2	1890
3	945
3	315
3	105
5	35
7	7
	1

Here the numbers used in dividing out, are

$2 \times 2 \times 2 \times 2 \times 2 \times 2 \times 3 \times 3 \times 3 \times 5 \times 7.$

Now, as there are three pinions, this series must be divided into

three parts; but it makes no difference where you divide it, and this circumstance makes the rule very valuable, as a great many trains can be made from the same series, and all exactly correct. Suppose we divide it thus,

$2 \times 2 \times 2 \times 2 \times 2$, $2 \times 3 \times 3 \times 3$, 5×7, then the product of the numbers in each part will be 32 — 54 and 35 for the number of the wheels forming the train of $\frac{7}{32} \times \frac{8}{54} \times \frac{8}{35}$.

These are the means generally used to get trains to represent fractions having a divisible denominator, with unity for the numerator; and I should advise any one in making a clock to keep as much as possible to ratios of this description, as they are by far the simplest. Fractions, with numerators, consisting of several figures, and denominators divisible by those numerators are the same as the fractions already mentioned, after dividing out, so nothing need be said on that point. Some times a train is required to make such a fraction as $\frac{19}{235}$, and here the numerator won't divide the denominator, therefore, the rule given above will be quite at fault; but as the denominator can be divided by 5, there is a very easy way out of the difficulty, by making two fractions of the original one. Thus $\frac{19}{235}$ is the same thing as $\frac{19}{47} \times \frac{1}{5}$ and we can multiply the last fraction by any number we choose, without altering its value, so we will multiply by a pinion of 12, by which means we get the train $\frac{19}{47} \times \frac{12}{60}$.

If the fraction in the last example had been $\frac{19}{239}$ instead of $\frac{19}{235}$, the number 239 would be too large to put on one wheel, and is not divisible by any number to make two of it, consequently it would be quite impossible to represent this fraction exactly, by any combination of wheels whatever.

These fractions often occur in making planetary machines, but can always be avoided in such things as turret clocks, and are therefore foreign to our purpose; however, as I have gone further already into the subject of trains than I intended at first, perhaps it is as well to shew you how wheels are usually made to represent these fractions by approximation, which is the last resource.

This is best done by the rule of alternate ratios, which is as follows:—Divide the greater number by the less, and the divisor by

the remainder, till nothing remains, also write down all the quotients so obtained.

Then 1 divided by the first quotient is the first ratio, and the terms of the first ratio multiplied by the second quotient, and 1 added to the denominator gives the second ratio; after which multiply the last ratio by the next quotient, and add on the foregoing ratio.

The fraction $\frac{19}{239}$ will, therefore, be operated upon in this way:—

```
19)239(12
   19
  ---
   49
   38
  ---
   11)19(1
      11
     --
       8)11(1
         8
        --
         3)8(2
           6
          --
           2)3(1
             2
            --
             1)2(2
               2
              ==
```

Here the quotients are

12· 1· 1· 2· 1· 2 giving

Ratios of $\frac{1}{12}$ $\frac{1}{13}$ $\frac{2}{25}$ $\frac{5}{63}$ $\frac{7}{88}$ $\frac{19}{239}$

And these ratios approach the truth nearer and nearer till they come to the original one if calculated right. Now the fraction $\frac{7}{88}$ is very near the truth, and can be used in its present form, or it can be divided into $\frac{7}{11} \times \frac{1}{8}$ if preferred, making thereby a train of $\frac{7}{11} \times \frac{7}{56}$ by using another pinion of 7.

If you wish to enquire further into this subject, you can best do so by referring to an article written by Dr. Pearson in Rees's Cyclopædia, under the head of Planetary Number, and in the same work, under the head of "Ratio," you will find valuable information on the same point.

We will now look at plate E, which shews the arrangement of wheels used in a 4 wheel train. The centre wheel B, generally

makes one revolution in the hour, and is used to work all the spindles for the minute hands, and to unlock the striking part by means of one pin. Sometimes this wheel makes half or a fourth of a revolution in an hour, and two or four pins are used for unlocking; but this plan is not to be recommended, because the slower these unlocking pins travel, the more uncertain will be their action in point of time. Now if one revolution per hour is fixed upon for this wheel, we can get the ratio of the upper part of the train by simply ascertaining the rate of the escapement wheel. And here I must observe that awkward fractions have often been introduced into this part of trains, by clockmakers beginning at the wrong end of the matter. It has been the custom with train calculators to fix upon an even number of inches at random for the length of the pendulum, and to calculate a train answering the number of vibrations given by this assumed length of pendulum, which method has the defect of making the time of vibration some queer fraction of a minute, difficult to be represented by wheelwork. Frequently the number can only be approximated, and it then becomes necessary to alter the length of the pendulum, so as to correct the error of the train. Many clockmakers know nothing about calculating trains, and they consequently make memorandums from what they have seen in other clocks, thus these odd numbers get copied from one clock to another, and it is common, even at the present day, to find trains representing most extraordinary ratios, and pendulums vibrating some very absurd fraction of time. You will see from these remarks, that the best way is to fix upon handy numbers for the train in the first place, and to calculate afterwards the length of pendulum suitable for that train.

Now as it takes two vibrations of the pendulum to let one tooth of the escape wheel pass, it follows, that the number of vibrations given by one revolution of this wheel are twice the number of teeth, and the calculation becomes very simple. A slow rate should be fixed upon for this wheel, which will make the escapement last for a great number of years, and it will suit a long pendulum, which is necessary, as the pendulum's ball ought to have considerable velocity, and still move in a very small arc. Suppose we

assume one revolution in two minutes for the rate of an escape wheel of thirty teeth, then the pendulum will make a vibration in two seconds, and the escape wheel must make thirty revolutions whilst the centre wheel makes one. As there are two wheels to get up this speed, we can divide the ratio by any two numbers which will make 30 by being multiplied together, such as 5 : 1 × 6 : 1, and there are evidently many such numbers, but when expense is an object, and you wish to save pattern making, by using the same wheels for the striking part and dial work, there are only a few numbers which will fulfil all the conditions required.

The train, $\frac{84}{50} \times \frac{50}{30}$ makes $\frac{1}{30}$, as can be proved by dividing the product of the wheels by the product of the pinions

$$140)4200(30,$$
$$420$$
$$\ldots\ldots$$

and it will presently appear that the wheels 84 and 50 will also suit the striking part and dial work.

The length of the pendulum can be found from this well-known rule: Divide 141120 by the square of the number of vibrations per minute, the quotient is the length in inches, thus 141120 ÷ 900 gives 156·8 inches, or 13 feet 0·8 inches for the length of this pendulum. The same thing can be done by a slide-rule, rather quicker and near enough, by inverting the slide in this way:—

Set 39·2 on	℄ Pendulum	180	157	88	56·3	39·2	28¾	22	14
to 60 on	D Vibrations	28	30	40	50	60	70	80	100

The ratio between the wheel C and pinion D depends on the number of revolutions given by the wheel in the course of a week, and this again is governed by the number of rope-coils on the barrel. Now where a clock tower is very high, barrels of large diameter can be used with light weights, requiring only small rope, and many coils can be put on the barrel without making it an awkward length. On the other hand, where the fall is more limited, larger weights, with thicker ropes, must be used, and the coils on the barrel will be fewer. You might suppose that a weight

of 4 cwt. falling 20 feet, would do as much duty on a clock as 2 cwt. falling 40 feet; but in practice it is not found to do so, owing to the friction of the pivots of the barrel being increased by the extra weight. And there is a further loss from the large rope being more rigid than the small one. As this matter depends entirely on the situation of a clock, it is impossible to form any general rule, so we will proceed by supposing the number of coils to be 32, and the time of going without winding eight days, then the number of hours required to run off the rope will be 24 × 8, or 192, and this, divided by the number of coils, 32, gives 6 hours for the time the wheel C takes to make one revolution, so if we make the pinion 12, the wheel will be 72, but instead of 72 let us use a wheel of 78, which is correct enough in this place, and will also suit the striking part, by which means we save a wheel pattern.

Before we finish with the going part, it will be necessary to go more minutely into the subjects of escapements and pendulums, as upon these depend the good performance of a clock. The adjustment of an escapement in a clock is as important as adjusting the valves in a steam engine, for if this is not properly done, the clock will not keep time, no matter how well the parts have been executed, and this is one reason why many rough old turret clocks perform better than new ones of superior workmanship. When an escapement is properly made, the vibrations of the pendulum will be nearly uniform in point of time, even when the force transmitted by the train varies, and in house clocks the force on the escapement wheel is sufficiently constant, but not exactly so, for it is impossible to make wheels true enough to communicate invariable motion. Now in turret clocks there are many disturbing causes, which will make this force more variable than in house clocks, such as difference of temperature, variation in the thickness of the oil, caused by that difference, damp, and the effect of wind on the dial work. In some cases this difference of force is so great, that in warm weather, after applying fresh oil, the pendulum will swing out till the pallets work to the very butt, and strike the rim of the escapement wheel. On the other hand, when the oil is thick, in cold weather, the same clock will become very feeble, and the are of the pen-

dulum will fall off till the pallets will scarcely clear the tops of the teeth, in which case the clock will be liable to stop. Formerly this difficulty was got over by using heavy weights, and applying immense pendulums vibrating through large arcs, with considerable recoil in the escapement. Hindley, the celebrated clock maker at York, used pendulums 52 feet 4 inches long to govern his clocks. Some makers adopted an extra train to drive the dial work. This train was only unlocked by the going part and allowed to move one minute at a time, by which means the variable resistance of the dials was taken off the going part. Smeaton (who was considered a great authority in turret clocks) recommended escapements to be made with a recoil, and the angle of escape six degrees; he also thought it advisable to make the teeth deep enough to allow the pendulum to swing double this angle without striking the wheel, when a clock is clean and the weather calm. You will soon see that for accurate time-keeping, a pendulum ought to move in a very small arc, and no man knew this better than Smeaton; but in his time the irregularity of force in turret clocks was so great, that he thought it judicious to give the pendulum motion enough for its arc to fall off five or six degrees without stopping the clock. As one of Smeaton's escapements is still extensively used, I shall presently shew it, with his method of striking it out.

We must now see how to prevent the irregularities of the train from having any influence on the escapement wheel, which is done by a piece of mechanism called a remontoire or rewinder. This is supposed to have been invented many years ago in France, but from various causes they were found to fail, and it is only lately that these rewinders have been made to answer the purpose.

The principle is to use the train only for winding up a small weight, and this small weight is made to act constantly on the escapement, with an equable force. When this is done, it is evident that the escapement is quite independent of the train, and plenty of weight can now be applied to the train, to drive it through wind and weather by main force, for it matters not how rough the wheels act, if they only get the small weight up. Although mechanism of this description seems simple, a great deal of ingenuity was ex-

pended, before a good plan was contrived, to keep the small weight in action during the time of winding it. The easiest and perhaps the best way to effect this, is to wind up a spiral spring by one end, so as to drive the escapement wheel by the other, and this simple expedient occurred to many persons, who tried it long ago, but it always failed, owing to some small matters of detail not being properly attended to.

In the year 1788, Thomas Reid, of Edinburgh, made a turret clock for St. Andrew's Church, in that city, with a rewinder, but it wore itself out in eight years, and often got wrong, thereby causing the clock to stop. Thomas Reid has written a very able work on clock making, in which he describes the failure of this apparatus, and he says that from what he saw, he considers that rewinders are worse than useless. His rewinder consisted of a common endless chain hung over two pulleys, one on the spindle of the escapement wheel, and another on a spindle driven by the clock. The spindle of the escapement had several notches cut in it side by side, and following each other like a screw; the other spindle had a wheel fixed on it with a number of sharp spikes sticking out from the rim. These spikes were not all in the same plane, but were bent sideways, so that every spike had a particular notch in the escapement spindle, through which it could pass when the notch came into the proper position, by the revolution of the escapement wheel. The action is this: the small weight hung on the chain is wound up by the clock, till one of the spikes comes in contact with the escapement spindle, and then the clock is locked. In the mean time the small weight draws the escapement wheel round, by means of its pulley, till a notch is presented to a spike, when the clock will be at liberty to wind up again. The next spike will be detained on the solid part of the escapement spindle till its own notch allows it to go through, and thus the motion is continued, one spike passing after another.

It is very likely that the failure of this apparatus, and Reid's opinion, deterred clockmakers in England from wasting time on rewinders, for we hear nothing more about putting them in practice till Dent made the clock at the Royal Exchange, and here he

was obliged to use one in order to fulfil certain conditions laid down by the Astronomer Royal. In France they got into use before this, and were improved by degrees, till nearly all the best turret clocks were made with them. A French clockmaker of the name of Wagner, distinguished himself by contriving movements for rewinding, some of which were to be seen at the great exhibition of fifty-one. One very ingenious rewinder of Wagner's was made in this way, as near as I can remember:—The second wheel of the train, with its pinion, is hung in the bottom of a swinging carriage, and the next wheel also turns in the carriage, but its axis coincides with the bearings of the carriage, and consequently it can communicate motion from the second wheel, which swings to the escapement wheel, which runs on fixed centres. This swinging carriage has an horizontal arm, with a ball on it, which has a tendency to turn the carriage round on its centres, and if the pinion of the lower spindle is placed in gear with a fixed wheel, this motion of the carriage will roll that pinion round, and drive all the upper wheels, together with the escapement. The pinion would soon run down out of gear, but the fixed wheel is attached to the barrel of the large going weight, and as soon as the pinion has rolled a small distance, the fixed wheel is unlocked and allowed motion enough to push back the pinion to the point from which it started. When this is done, the pinion presses back the carriage and raises the arm with the ball, so that the ball is continually exerting force on the pinion, to turn it round. The fixed wheel is a worm wheel, and works into an endless screw, as well as into the pinion. The screw passes up near to the arm of the ball, and has a star wheel, which comes in contact with a pin fixed on the arm when the arm is elevated, but clears it when the arm is depressed, so that as soon as the arm arrives at the lowest point, the fixed wheel and screw are set at liberty, and they will go on till the arm is raised high enough to bring the pin in the way of the star wheel, when the fixed wheel and screw will remain locked till the arm falls again. On the top of the screw spindle is a fly, with wings, driven by a ratchet-wheel, which moderates the motion and slips on the ratchet, when the star wheel meets the pin, by which means the motion is

stopped quietly. It is clear that in this motion, the escapement is only driven by the weight of the ball, so plenty of weight can be applied to the fixed wheel to drive the dials and do the rough work, without interfering with the force on the escapement.

At Plate F is shewn another French rewinding motion, which is easier to put in practice, and amounts to the same thing. A, is part of the clock frame, which has a bracket, B, to hold the ends of two spindles, C and D. The spindle C is driven by the centre wheel of the clock, and carries a wheel at one end to work the spindle E, and a bevil wheel at the other end, working into another bevil wheel, moveable round the loaded arm F. The bevil wheel on this arm gears into another on the spindle D, and this spindle by means of a wheel and pinion, drives the escapement, G. The escapement spindle is prolonged through the clock frame, and has two notches cut through it side by side, and opposite each other, so as to allow one of the two arms, H H, to pass for every half revolution of the escapement wheel. The spindle E is provided with a fly to regulate the rewinding, and to take off the force of the blow when the arms H H strike the escapement shaft. The movement is this:—The centre wheel of the clock turns the spindles C and E, till stopped by one of the arms, H, meeting with the end of the escapement spindle. At the same time the bevil wheel N raises the arm F, and the weight of the ball is brought to bear, so as to turn the spindle D, by means of the two bevil wheels S and T. The bevil wheel N is now fixed, and the arm, in descending, rolls the bevil wheel S over it, and turns the bevil wheel T so as to drive the escapement. This action continues, till a notch in the end of the escapement spindle allows one of the arms H to pass, when the clock will wind up the ball again, and lock itself, after it has turned the spindle E half a revolution. If this escapement makes a revolution in two minutes, it will let go the clock at the end of every minute, and the wheels in the lower part of the train will move the hands one whole minute at once, and then remain stationary till the next minute has elapsed. This movement is generally made with three bevil wheels, and a large wheel on the spindle C, containing a great many spikes, which pass

through a number of notches in the escapement spindle, in the same way as in Reid's motion.

This plan is objectionable, because the spindle C presses the spikes with considerable force against the escapement shaft, and of course any variation in the force of the train will affect the escapement, more than if we use long arms pressing lightly on the escapement shaft. I put a rewinder something like plate F to a turret clock at Cyfarthfa, which answers well enough, but instead of unlocking with notches, which requires very nice workmanship, part of the arm F was so arranged as to come in contact with a wheel on the spindle E, made with four prongs, which lets off the clock every half minute.

In all these rewinders, acting by gravity, the variable resistance of the dials is done away with, but several wheels are still working with the escapement, which prevents the force being perfectly uniform; however it is sufficiently so for the escapement to correct the errors, if it is properly adjusted. When greater accuracy is required, a rewinder with a spiral spring must be used, which does away with the error of the wheels altogether. It is difficult to get a spring of the right strength, and several must be tried before you can get one to answer the force of the train, but when this is done, the force on the escapement is very constant, even when the going weight is increased or diminished by one half.

Some years ago I contrived a spring rewinder, which answered the purpose with very rough workmanship. It was made in this way:—The upper spindle of the clock is cut off at about the middle, and turns with one end in the clock frame, and the other in a bracket fixed half way between the clock frames. The end at the bracket passes through, and carries a spring box with a small arm fixed to it, and a hole is drilled in the end of the spindle inside the box. The escapement spindle works with one end in the frame, and the other in the hole above-mentioned. On the escapement spindle is fixed a spiral spring, which hooks inside the spring-box, so that when the first spindle and box are turned round, the spring acts on this spindle, to turn it also. The escapement spindle has the outer pivot long enough to reach through the frame, and on

the end of it is fixed a small crank. This crank, by means of a connecting rod and spanner, works a small rocking shaft with a crutch on it, and this crutch, by moving backwards and forwards, unlocks the arm on the spring-box at every half revolution. The spindle first described passes through the frame, and has a fly on it, to regulate in the usual way. I have shewn these three last rewinders, becuuse they are easy to make, but there are many in use, which I need not describe, as they require great accuracy in their construction, and would fail with our rough workmanship. The spring rewinder transmits force with perhaps greater regularity than any other contrivance, but after all there are small errors existing, because where there is a variation in the force of the train, there will also be a slight difference in the power required to unlock it. The spring is also rather stronger when first wound up, and its strength is affected likewise by change of temperature. Before speaking of escapements, it will be necessary to say a few words about the motion of a pendulum, that you may see what an escapement is required to do. We need not go into the mathematical investigation of all the properties of a pendulum in motion, as it is a complicated matter, and many able mathematicians who have already done so, give us all the results we require. Huygens discovered that if the ball of a pendulum could be made to vibrate in the arc of a cycloid, all the vibrations would be performed in the same time, no matter how much the length of arc varied, and he fixed upon a very ingenious way to make a simple pendulum describe this curve. He found out that if a cycloid is cut through at the centre, and the two parts are reversed or turned end for end, they will make a pendulum hung between them describe the original cycloid, if the pendulum is the same length as one of these half curves. These curved pieces were called "cycloidal cheeks," and were tried in practice, but failed, because the theory supposes a pendulum rod to be of an invariable length, perfectly flexible and void of weight, which in reality is not the case. If a pendulum ball moves in a very small circular arc, the curve approaches so near to that of a cycloid, that in practice they may be considered the same, and the pendulum will vary

a little in the length of its arc, without making any material difference in the time of vibration. The same thing can be proved in this way:—All chords in a semicircle are fallen through in the same time, and if it was possible to make a pendulum describe these chords instead of a circular arc, its time of descent would not be affected by the length of vibration. Now it is quite clear that we can't make a pendulum do this, but we can reduce the angle of vibration, till the arc is nearly of the same length as the chord. When a simple pendulum swings in the arc of a circle, if the length of vibration changes, the difference in time due to that change is given by Professor Bridge, in a formula, the substance of which is this:—Take the square of the short arc out of the square of the long arc, and this difference, divided by 52520, gives the error in parts of a vibration. The arc here mentioned is the number of degrees out of the perpendicular, or half the angle of vibration. The above rule can be put in a more convenient form, by dividing the number of seconds in twenty-four hours, by the above number, 52520, which gives the number 1·64, and the rule will then be this:—Multiply the difference of the squares of the arcs by 1·64, and the product is the error per day, in seconds. My object in giving this rule is to point out the following curious circumstance:—Let one pendulum swing 2° from the perpendicular, and another swing 4°, and let them both be brought to time, then if we increase the two angles by the same quantity, say 1°, any one unacquainted with the motion of a pendulum, would suppose that the time of vibration in the small angle would be more disturbed than in the large one, but the reverse is the case.

The error in the small angle is only 8·20 seconds lost per day (9—4), or 5 and 1·64 × 5 give 8·20, but the error in the large angle will amount to 14·76 seconds per day.

(25—16) is 9 and 1·64 × 9 = 14·76.

Having shewn a little of the laws governing pendulums when swinging freely, it will be necessary, in the next place, to make a few remarks concerning pendulums influenced by an external force. If, by means of an escapement, we artificially increase the force of gravitation, we shall make a pendulum pass through its arc in a

shorter period of time, and if we do the reverse we shall cause a pendulum to vibrate slower, but we can increase the effect of gravity through one half of the arc, and lessen it through the other half, without making much difference. Theory and practice show, that a pendulum is more disturbed by an impulse given at the end of the arc, where the ball is moving slow, than if given in the middle, where the ball travels with considerable momentum; and experience also teaches us that a pendulum is less affected by a strong impulse of short duration, than by a weak one acting through a longer space.

We now see that to make a clock keep time, a pendulum must move in as short an arc as possible, and must receive from the escapement a strong, short impulse, when the ball is near the lowest point. The escapement must also be adjusted, so as to make the impulse in one part of the arc counteract the disturbance caused by the force given in the other. I shall say nothing about the old crown wheel escapement, which is quite out of date, and was a bad piece of mechanism in every respect. The "anchor escapement," invented by Dr. Hook, is still used in common clocks, and will go with very bad workmanship. It has considerable recoil, and when a clock with this escapement is brought to time, if more weight is applied, so as to increase the force of the escapement, the clock will be found to gain, because the train opposes the pendulum ball in its ascent, and helps it in descending. If, on the other hand, weight is taken off, the clock will lose, which shews clearly, that a pendulum driven by this escapement is affected by every small change of force in the train, and will consequently not keep time.

Smeaton's escapement takes in fewer teeth, and the recoil is not so great as in Hook's, but still it has enough to cause an increase of rate, if more weight is put on the train. Although this escapement moves a pendulum through too large an arc, and requires much force to drive it, still it is an improvement on the last, and keeps time tolerably well, when the clock has an iron pendulum rod, for in warm weather, when the oil is thin, the train will become rather stronger, and would make the clock gain, but the expansion of the rod from the same cause, will have a contrary

effect, so the two errors will in some measure correct each other. Smeaton's escapement is shewn at Plate G, and is struck out thus:—

Count three spaces from the upper tooth, and divide the next space into four equal parts. Draw A B, and erect a perpendicular at the third division, which will cut the line, A C, and give C for the centre of the crutch. On the other side draw a line, D, through the second division, parallel with A C, and cut it to length by an arc, E, passing through the third division, with C as a centre. Draw the arc, G, from this point of the crutch, till it cuts the arc, E, which gives the other point of the crutch. The arc between the line, N, and the third division must be doubled, which gives the angle, N C H, called the angle of escape. This angle must be copied at the other side, and P S must be made equal to D H. With centre S and radius C E, describe a small arc, Z, with the end of the crutch as a centre, and the same radius as before; intersect the former small arc, which gives a centre from which to strike a curved face, S, having the same recoil as the face, D, and the two ends of the crutch will act exactly the same in every respect.

Another escapement, acting with a recoil, is the gravity escapement, in which a wheel lifts two small weights, and these, in descending, act on the pendulum by their gravity only. As the impulse thus given is invariable, it was supposed that a contrivance of this kind would make a pendulum keep time exactly, and at first sight it seems very likely to do so, but as the pendulum is obliged to unlock the wheel, it will be affected by any variation in the force of the train, and will, consequently, vary a little in its length of stroke.

This change of stroke produces an error, for the weights travel with the pendulum to the end of the arc and back again, so if the pendulum makes a longer vibration than usual, the small weight will oppose it in ascending, and accelerate its descent exactly as a common recoil escapement would do. Another objection to this motion is, that if the train is not very well made, the variable force will sometimes scarcely lift the weights, and at other times the

weights are lifted too quick, in which case the hooks will go out too far, and let the wheel run wild. A great deal of ingenuity has been expended on guards and catches to prevent this, but after all, the motion has the radical defect before mentioned, of gaining in the long arcs.

The next escapement is the "dead beat," in which the teeth give the impulse, after sliding along a circular part, drawn from the centre of the crutch, and in this case there will be no recoil. If it was possible to make the points of the teeth fall exactly at the beginning of the sloped part, half the impulse would be given while the pendulum was descending, and the other half during its ascent, in which case any variation of force would make very little difference. In practice, however, this can't be done, and we are obliged to make the tooth fall on the circular part of the crutch, a little distance from the corner. Now let us take the arc passed through by the pendulum, from where the tooth drops on the circular part, to where it escapes, and we shall find that the impulse in the first half of the arc, while the pendulum is descending, is less than in the second half, where the pendulum ascends, because the circular part of the crutch does nothing. This lessens the effect of gravity on the pendulum, and a clock with this escapement will be found to lose, when more force is applied to the train, and will gain if weight is taken off.

As this error is caused by the tooth not falling exactly on the corner, it is quite clear that the nearer we come to this point, the less will a pendulum be disturbed by variable impulses, and some escapement makers, by first-rate workmanship, get the teeth to fall so near this point, that a clock will vary very little by a change of force in the train.

You have seen that a common recoil escapement causes a clock to gain, when the force of the train is increased; and if a dead-beat escapement does quite the reverse, it is reasonable to suppose that there must be a point between the two, where these effects will be neutralized. In practice this is found to be the case, and a clock will keep time very nearly, when the right amount of recoil is used, but no exact rule can be given, as it depends upon the dis-

tance from the corner at which the teeth drop. If the teeth fall near the corner of the slope, very little recoil is required, but where the teeth fall further on, the recoil must be increased; as this distance is very little, and can't always be made the same, it will be necessary to adjust the recoil by actual experiment in every case, with the crutch itself, and before hardening the crutch this can easily be done. The first escapement on this principle was tried by Berthond, of Paris, who called it an isochronal escapement, because all the vibrations are performed in the same time, and it is now often used in turret clocks, because it is well calculated to counteract the effects of disturbances, provided the recoil is properly adjusted. The last escapement I used for a turret clock is very like Berthond's, but the teeth are curved instead of being sharp pointed; the angle of escape is much less, and the beginning of the recoil faces on both ends of the crutch are the same distance from the centre of motion. This answers the purpose very well, and is shewn at Plate H, with the way in which it was struck out. Divide one space into four equal parts, and through the first division draw the line, A C; make the distance, A C, equal to the diameter of the wheel. From C, with radius B C, describe the arcs, B E and G H. Draw B L parallel with A C, and from C, with radius C L, describe the arc O. Draw the tangent, O G, which gives the direction of the slope, G M. We have now a dead-beat escapement, in which the teeth fall on both ends of the crutch at the same distance from C. Now if the tooth slides up an incline, B P, instead of following the dead circle, B E, it will have a certain amount of recoil, and this gradient can be adjusted without altering the sloped part, which gives the impulse. The distance shewn from B, where the teeth drop to the beginning of the incline, is too much; about half this distance is quite enough, if the wheel is anything like true, and the gradient will be then 1 in 4. Measure four spaces along the dead circle from B, and from this point mark off one on a radial line towards C, then with radius, C B, and these points, as centres, describe the short arcs at S, for a centre from which to draw the incline. As there is some uncertainty about the point, B, the best way is to make the gradient too

steep, and try the crutch in this way. Put just weight enough on the clock to keep the escapement in motion without stopping, and bring the clock to time as near as possible, by adjusting the length of the pendulum. After this is done the weight must be increased, till the pendulum swings out to about double the angle of escape, and if the clock still keeps time, the escapement is already adjusted. Should the clock gain with the increased weight, we must cut away the incline at P, to lessen the recoil, but if it loses, it shews that the incline is not steep enough, and a new crutch must be made. This adjustment is soon described on paper, but in practice you will find it a work of time, as it is necessary to try the weights for several days after an alteration has been made. In getting the pendulum to length, you will find this rule save much time and trouble:— Multiply twice the length of the pendulum in inches, by the seconds lost or gained in twenty-four hours; divide this by 86400, and the quotient is the quantity the pendulum should be altered, in parts of an inch. The crutch must also be fitted so that one tooth falls on B, just as the other leaves M, and in the same way, when one tooth is on the point of leaving the corner of D, the other must be nearly touching G. The nearer this can be done the better; but a little slack or drop is necessary to make the crutch clear the back of the teeth, and care must be taken to make the drop the same at both ends of the crutch. The drop added to the thickness, B D ought to be half a space, and if this is properly attended to, the wheel will move exactly half a space at each escape. When the crutch has been properly struck out, it will be moved through the same angle both ways, by the teeth passing along the slopes; however it is well to fix a temporary pointer, of considerable length, on the crutch, to see that this really is the case. The distance A C depends on the number of teeth taken in by the crutch, thus a tangent to the wheel at B will intersect the centre line at C; but a tangent from the tooth Z would intersect the centre line much nearer to the wheel. The longer the arms are the smaller the angle of vibration can be made; but if this is carried to an extreme, the escapement will have too much leverage over the pendulum, and will consequently disturb it.

Perhaps ten teeth taken in, (for a wheel of thirty teeth), as shewn on the drawing, is as good a number as any, and the distance A C is then simply the diameter of the wheel.

Having adjusted the escapement, we must next see that the pendulum and crutch move in parallel planes, which is done by taking away the escapement wheel, and swinging the pendulum through long arcs by hand, when any untruth, in this respect, will show itself by a sliding motion of the pendulum rod in the fork which drives it. When this is the case, the cock or bracket holding the pendulum spring must be twisted by gradually slackening the screws at the end, and driving thin steel wedges behind it, till the sliding motion ceases. We must also take out the crutch, and look through the two pivot holes, to see that the spring is in line with the axis of the crutch, and this axis must also be in line with the point at which the spring begins to bend. If this is far wrong it will be shewn by the fork sliding up and down the pendulum rod, and must be rectified before the bracket is permanently fixed. Lastly, the escape must take place when the pendulum has moved the same distance both ways out of the perpendicular, which is called putting the clock in beat, and is generally done by bending the shank of the fork; but a better way is to fix the crutch by a friction spring. sufficiently strong to resist the force of the escapement wheel. This will allow the crutch to be turned on the axis when extra force is applied, and it has the further advantage of preventing the wheel getting broken by the pendulum. This accident cannot happen with a clock in motion, but if the train stops from any cause, the pendulum will continue in motion for a short time, and the point of a tooth will sometimes meet the point of the crutch, in which case the momentum of a heavy pendulum ball, moving at the end of a long rod, is more than sufficient to break the escapement.

The length of pendulum given in a former rule, is the distance from the point of suspension to the centre of oscillation, but in practice the rod must be much longer, as its weight brings the centre of oscillation higher up, and because a pendulum spring also makes a pendulum vibrate faster. The centre of oscillation is rather below the centre of gravity, but for our purpose it will be

near enough to take the length from the centre of gravity, and this will make the pendulum a little too long which is a mistake on the right side. The easiest way to make a new pendulum, of nearly the right length, is to cut a long strip of wood to the theoretical length, for a gauge, then, if we place the pendulum across a sharp edge, we can move the ball till the balancing point is the same distance from the point of suspension, as the length of the gauge. The weighted lever P, Plate E, is intended to keep the clock in motion during the time of winding. It is made to slide sideways, so that its end can be inserted between any two teeth of the centre wheel which come within its range.

Before we finish with the going part it will be advisable also to show the effects of temperature on a pendulum. If we take the greatest change at fifty degrees, the expansion of the following substances in parts of the length will be nearly this:—Deal, .000113; bar iron, .00035; steel, .000315; brass, .0005; zinc, .000815. We can find the error in time due to a small change of length, by altering the rule formerly given for regulating pendulums into this form: multiply the change of length by 43200, and divide by the length of the pendulum for the daily error. Now the change of length in this case is the expansion multiplied by the length of pendulum. In this calculation the length of pendulum is used first as a divisor, and afterwards as a multiplier, consequently it can be omitted, and we have this simple rule: multiply the number representing the expansion of the material used by 43200, which gives the error in seconds per day. Thus we find that if a clock, with an iron pendulum rod, keeps time in winter, and the temperature is raised fifty degrees higher in summer, the clock will lose at the rate of 15 seconds a day. It is seen by the numbers given for different materials, that iron expands more than three times as much as deal, therefore a deal pendulum rod will keep time better than iron if we can only prevent its absorbing moisture, and this is best done by keeping it up a chimney for a long time, and then varnishing it over several times. A deal rod ought to be made as slight as possible, for it will vary less from damp, and the weight is more likely to keep it from warping. About 2 ins. × inch

is a common section for a rod about fourteen feet long; but you are not likely to want a ball heavier than three hundred pounds, and this can be safely carried on a much thinner rod. In the best Astronomical Clocks the effects of temperature are nearly done away with by means of compensation pendulums. The two generally used are the mercurial pendulum, invented by Graham, and Harrison's gridiron pendulum, in which several brass bars expand upwards, so as to counteract the expansion of the steel downwards. Graham's pendulum could not be used for a large turret-clock, as the expense of the mercury would be enormous, and Harrison's pendulum would be very heavy and clumsy, if made fourteen feet long, as it requires five steel tension rods acting against four brass compression bars, and the latter bars must be strong enough to sustain the weight of the ball without bending. Large pendulums are now generally compensated by iron acting against zinc, and here only one zinc compression piece is required, as zinc expands much more than brass. These large pendulums are made in this way—a zinc tube rests with its bottom on the end of an iron rod, which passes through the tube, and goes up to the suspension spring. Over the zinc is passed another thin tube of iron, which rests with its upper end on the top of the zinc tube by means of an internal ring, and the lower end carries the ball. The length for the zinc is found by multiplying the length of iron by .3973, but the length of iron is the length of the pendulum added to the length of the zinc; so several trials must be made before you will get the length for the compensation. It must be borne in mind that this pendulum will answer when the tubes are well made so as to slide freely; but if the tubes get bent by accident, or the sliding is stopped by dirt, corrosion, or any other cause, this pendulum wont keep time as well as a common deal rod.

We now come to the striking part of a turret-clock, the construction of which does not require as much science as the going part; but there are matters of detail which must be attended to, or else the performance wont be satisfactory. In house clocks, where there is no difficulty in winding up weight enough, a little waste of power is of no great consequence, but in turret-clocks winding up

the weight is a laborious operation, and here it becomes necessary to economise the force so as to work a heavy hammer, and still keep the large weight of reasonable size. There are two contrivances for giving the right number of blows, one is the old locking-plate spoken of before, and the other is the repeating mechanism, or rack and snail motion. If we take all the blows struck by a clock hammer in twelve hours, they will amount to 78, so if we divide a circular plate into 78 equal parts, and cut notches, in the two first divisions, then in the fourth, seventh, and so on, the spaces between the notches will be in proportion to the number of blows for each hour. This is called a locking plate, because the clock is locked, after striking the right number of blows, by a catch falling into one of these notches. In some clocks locking-wheels are used with pins to force levers up instead of notches to let them drop, and the mechanism has been arranged in a variety of ways; but after all the principle of dividing a wheel into 78 is exactly the same in all these striking parts. I have generally used the striking part shewn at Plate E, which answers very well, and requires no great nicety in the execution of the parts. The large wheel A, of 78 teeth, makes one revolution in twelve hours, and is driven by a barrel with sixteen coils of rope, which will keep it going for eight days. The wheel A is fixed on the spindle, but the barrel turns loose, and has a wheel fixed on one end similar to A, working into a pinion F, by means of which the weight is wound up. The reason for using sixteen coils is that it makes the wheel A go the same number of turns in twelve hours as the locking wheel E, and this wheel can be fixed at once on the same spindle, by which means extra gearing is avoided. The pinion on the striking shaft must have the same number of teeth as the number of pins or cams on the striking wheel "I."

In theory it matters not how many pins are used provided the number of the pinion is the same, but in practice we find that the larger this pinion is made the less will the power be lost by friction on the pivots of the striking wheel. This is a matter of greater consequence than is generally supposed, and is one reason why many clocks wont lift a hammer sufficiently heavy to get the full

sound out of a bell. The locking lever, N, makes one revolution for each blow of the hammer, so if the wheel "I" has 84 teeth and 12 pins, the pinion on the spindle of the lever must have seven teeth as the ratio between the wheel and pinion must be the same as the number of hammer-pins. The wheel L has 50 teeth working into a pinion of 12 on the spindle of the fly, so the fly will turn somewhere about four times for one blow of the hammer. The rate of the fly is not very material, but it ought not to go much faster than this, as a small fly revolving fast will cause more friction than a large one going slow, and of course, in the latter case, a heavier hammer can be raised with a given amount of weight.

When the fly makes about four or five revolutions for each blow, 120 square inches of wing, fixed at 13-inch radius, will be found about enough to regulate a clock with a hammer of 25lbs, but no exact rule can be given on this point, and it is advisable to make the wings too large at first, as they can easily be reduced. At Plate E, the lever W is drawn a little out of its proper position, in order to show the two locking pins on the lifting piece, G; but in reality, when the clock is locked, the lever stands upright, with its pin pressing against the first pin in the lifting piece. Towards the end of the hour, the piece, D, begins to raise the lifting piece, and when it is sufficiently high, the pin in the end of the lever, N, will pass under the first locking pin of the lifting piece, and will proceed till stopped by the second pin, which is now standing in the way. The small motion thus allowed to the train when the pins are changed, is called the warning, and in some clocks the train is allowed to move a great deal, before the second locking takes place, but this is very objectionable, and you will soon see that the less warning we allow, the better. The lever, N, is detained on the second pin till the end of the hour, when the piece, D, allows the lifting piece to fall back to its original position. The lever will now pass over the second pin, and by the time it has made one revolution, the tooth of the locking wheel will have moved enough to let the lifting piece fall further down, so as to be out of the way altogether. The clock will continue to strike till the next tooth of the locking wheel raises the lifting piece high

enough for its first pin to catch the end of the lever, and thus the clock will be stopped. Perhaps it is as well to observe, that the locking wheel ought to begin to raise the lifting piece directly the lever has passed the pins, before striking the last blow, as it will give the lifting piece plenty of time to rise, and more bevil can consequently be given to the teeth, so as to raise it quietly, and without much strain. It will be seen by the drawing, that at one o'clock on the locking wheel, there is not sufficient angular distance to contain two teeth, so one double tooth is used, but this makes no difference, as the lever, N, can always make one revolution after being unlocked, and the lifting piece can remain on the top of the tooth, ready to lock it again. The lever, H, is acted on by the striking wheel, so as to draw down a wire, by which means the hammer is raised, as shewn at Plate Z, where the end of the wire can be seen. This wire must have a certain amount of slack, when the piece, H, is touching the face of the cam, for if this is not the case, the hammer won't have time enough to fall on the bell before the next cam meets the piece, H, and in this case the striking wheel will receive the force of the blow. As this slackness in the wire wastes motion, it is clear that the hammer ought to fall in as short a time as possible, and this depends on the elevation of the hammer shank, as well as on the distance fallen. It has been found, by experience, that after a clock hammer has fallen four inches perpendicular, it is then going at the proper velocity for striking a large bell, and the effect of elevating the hammer shank can be seen at Plate L. A, B, and C, are three balls, supposed to be standing on a level line, and D D is another line, four inches lower than the first, and parallel thereto. Let A fall perpendicular, and B roll down an incline, and C roll down another of less inclination than the first, then if there is no friction in the case, it can be proved that the three balls will be moving at the same velocity when they arrive at the line, D D, but it is evident that C will be longer on the journey than B, and B wont get to the line as soon as A, which shews clearly that to strike a blow of a given force in the least time, the shank of a hammer ought to stand level when the hammer is raised half way up. Owing to the shape of bells,

a hammer striking downwards would have a tendency to slip off, instead of striking at right angles with the surface of the bell. So we are obliged to elevate the shank, as shewn at E, but we must mind that this is only done just enough to make the hammer meet the bell fairly, and no more, for the greater the elevation the slower the motion of the hammer will be. It is also plain that considerable force must be applied to lift a hammer at the commencement of the motion, but after it has been raised a certain distance, the force required is much less. It is unfortunate that the greatest force is required when the motion begins, for the clock is then partly employed in overcoming its own inertia, and cannot exert as much force as afterwards, when the train is fairly in motion. This defect is best remedied by making the shank very long, so as to reduce the angular motion, but if we use a shank more elevated, we shall only increase the evil. This matter appears so simple, that you will perhaps think it useless my making these remarks about hammers, but I have done so, because it is very common to see hammers elevated 45 or 50 degrees, and many clockmakers fancy that these elevated hammers, by moving through a very long arc, must of necessity strike a very hard blow, forgetting that the same velocity would be produced by falling very little, if the shank was elevated only 35 or 36 degrees, which is quite enough. The warning, or moving of the wheels when the train is being unlocked, ought to be very little, as the clock will then have the slack of the wire to take up after starting, and it will consequently have time to acquire momentum before it begins to lift the hammer, but if the wire is tightened during the unlocking, the clock will have to start with the weight of the hammer acting against it, and then, of course, it cannot lift one so heavy. In some clocks the hammer is raised by means of pins fixed in the side of a wheel, as shewn at Plate T, where it will appear that the action begins a considerable distance from the end of the lever, and of course this shortening of the lever makes a hammer harder to lift at first, than when the pin is afterwards acting on the end. This is exactly what we dont want, and another defect in this mode of lifting is, that after

the hammer is raised the lever is obliged to slide over half the diameter of the pin before it can fall, so that some of the motion is lost. There have been many contrivances to lessen the resistance of the hammer, such as toothed sectors working into short segments on the striking wheel, and some clockmakers have been ignorant enough to employ large friction rollers instead of pins, thereby diminishing the fall by half the diameter of the rollers. The simplest plan and the best is to use a wheel with cams like B C, for here the action begins on the ends of the lever, and the motion imparted will be nearly uniform, if a proper curve is used for the face of the cam. Another advantage is that the lever falls from the very end of the cam and gets all the motion. In making this wheel the back of the cam must be struck from the centre, A, with a longer radius than the lever, in order to allow space for the hammer to fall before the next cam takes the lever; and when the clock is locked after striking the last blow, the lever ought to only just clear the last cam, which will leave all the spare space between the lever and the next cam. If the lever is now made to touch the face of the cam, the wire will be slack as before described, and the clock will have a little space to run before meeting the resistance of the hammer. As the face of the cam is of considerable length, it ought to be formed to the proper curve, which can be done near enough, by rolling a small circle over another made to the radius, C B. Denison gives a formula for the diameter of the small circle which, in words, is this:—Multiply A B by B C, add to this B C squared, and extract the square root, then the difference between this quantity and B C will be the diameter of the generating circle, D. After the curve is drawn to suit A B, the length of the lever must not be altered, for if we cut it shorter it will scrape the face of the cam, and if too long motion will be lost; so any space allowed for the fall of the hammer must be got by cutting away the back of the cams. The numbers for the wheels, at plate E, are not given as the best that can be used, for many others will fulfil the required conditions equally well; but they have the advantage of saving patterns, as the same numbers are used for the going and striking part, and the wheels I and L can be used for the dial work

also. The dial work is so simple that little need be said about it, and the arrangements depend so much on the situation of the clock, that the same plan wont suit in every case. Perhaps the best way to make the dial itself is to cast it about $\frac{5}{8}$ thick, with a hole 2 feet diameter at the centre. Round the edge of this hole a shoulder must be cast, at the back, so that a light plate can be made to fit the hole, with its back against the shoulder and its face flush with the face of the dial. A brass tube passes through the centre of this plate, and carries the hour hand at one end, and the other end goes through a bracket screwed to the plate. On the tube, between the bracket and plate, is fastened a wheel of 84 teeth, and the tube has shoulders to keep it safe endways. A spindle turns in this tube with the minute hand fixed at one end, and a wheel of 50 teeth is fastened on the other end, outside the bracket. This spindle is driven by the centre wheel of the clock, the motion being conveyed by means of long rods and universal joints; and a little slack endways must be allowed in these to prevent the spindle getting jammed by the expansion of the rods. The bracket and plate carry another short spindle, with a wheel of 50 teeth on the outer end working into the other wheel of 50, and the spindle has also a pinion of seven teeth which drives the wheel on the brass tube. It will be found convenient to make this short spindle capable of being taken out of gear, by which means the position of the hour hand can be easily adjusted with respect to the minute hand. The advantage of the centre plate is, that the whole of the dial work can be put together on the ground, hands and all; and the plate can be raised outside the tower by means of rope yarn, till the plate comes opposite the recess in the dial, where the bracket and wheels are drawn in through the hole, and the plate can be secured by screw pins from inside. Dials are often made with only a small hole to put the spindle through, and the hands are afterwards fastened outside by means of a long ladder; but this is not as good a plan, for a man can always fasten on the hands better in the shop then when standing on the end of a long ladder. When three dials only are used, the long rods can be driven by three bevil wheels; but if four are required, it will be necessary to have an upright shaft

with a bevil wheel at the top, working four others opposite the dials, and this will make the wheel work complicated; for there must be seven bevil wheels to work the rods, and the wheels altogether for this dial work will amount to no less than twenty-three. So, in most cases, it will be advisable to avoid using more than three dials. In setting the hands, you will want to move the dial work altogether, with the piece which unlocks the striking part, without interfering with the going part; so it will be necessary to have means of detaching one part from the other. This is done in a variety of ways. Some clockmakers fix a wheel on the spindle of the centre wheel by a friction spring, and this works into another on a spindle, which unlocks the striking part and drives the dials; so that when extra force is applied, the last spindle can be turned independent of the clock; sometimes the wheels are fast and the spindle is allowed to move endways, so that you can slide it out of gear, and after turning it the necessary quantity, you can put it in gear again. In some clocks instead of a friction spring, a plate with sixty notches is fixed on the spindle, the wheel runs loose against the side of this plate, and carries a spring catch which drops into one of the notches, so that by drawing out the catch, the spindle can be turned as many minutes as required; I have generally used the two ends of the centre wheel spindle itself to drive the dials, and loose off the striking part. The centre wheel and pinion are made in one piece, and form a pipe through which the spindle passes; the spindle is made to jam the pipe fast by a collar at one end and a lock-nut at the other, so by using a common spanner the hands can be set and the wheel fastened at any time. This is not exactly the way a professional clockmaker would do the thing; however, it answers the purpose, and saves two extra wheels and one spindle.

Sometimes repeating motions are used for the striking parts of turret clocks, and they have one advantage over the locking plate, which is this: If the striking part is allowed to run down, or it is made to strike by accident, it will be necessary, with a locking plate, to make the clock strike several times, so as to bring it to its place again; but with a repeating motion, the hour struck will

always agree with the hour hand. This is, no doubt, an advantage, but the old locking plate motion is generally preferred in turret clocks, for these reasons: The repeating motion requires a wheel, turning in twelve hours, to work the snail, as well as a spindle, turning once in the hour, to unlock it, and this encumbers the going part with extra wheel work. There are more levers used than with a locking plate, and they require very good workmanship to make them act with certainty. Should the train (by chance) fail to start when unlocked, the tail of the rack will remain in contact with the snail, and will stop the going part as soon as the one o'clock step comes round against it. This defect can be remedied by using a spring on the tail of the rack, which gives way and allows the snail to pass; but this is adding to mechanism which is far too complicated already. Another disadvantage is, that we cannot make the rack fall to a certainty when the oil gets thick, without using a spring tolerably strong; and, as the clock is obliged to move the rack back again while striking, the resistance of the spring will consume force which ought to be employed in lifting the hammer.

Striking parts, for striking the quarters, are nearly the same as for the hours, but the locking plate is generally fixed on the spindle of the striking wheel, and is divided into ten parts instead of seventy-eight. The number of pins or cams must also be ten, which will answer for one revolution in the hour, and at the last blow, a pin fixed in the wheel unlocks the hour part, which will start just as the quarters finish.

Sometimes to prevent the first blow of the hour being effected by any difference in the time occupied in striking the quarters, the going part is made to let off the quarters some time before the end of the hour, and it lets off the other part also when the hour is finished. In this case a quarter part can be made with a repeating motion; but if the hour part is unlocked by the quarter part, it is clear that a repeating motion can't do more than a locking plate, for the hour part will start as soon as the pin wheel has completed a revolution. Where barrels are made to ring changes on several bells, locking plates only should be used; for if a repeating motion

got unlocked by accident, it would mix the changes and throw all into confusion.

The force lost by friction and so forth in a striking part, can easily be found, thus :—Multiply the perpendicular fall of the hammer by its weight, and by the number of blows struck in eight days, which is 1248, this represents the actual work done. The power consumed is the large weight multiplied by the fall in the tower, so if we divide one by the other we shall have the yield. Where a clock is well made with cams, this loss is found to be about half, but if pins are used for lifting the hammer and much warning is allowed, about one-third of the power is the most that can be obtained.

Modern clockmakers frequently use three wheels in the trains instead of four, and this is said to be a vast improvement, as it lessens the friction, and the clock is also supposed to be simpler. That the plan does away with some friction is certain, but these modern clocks are quite as complicated as the old four-wheel method, and in some respects they are more difficult to make. Let us suppose the centre wheel to turn in one hour, and the escapement in two minutes, then one wheel and pinion to do this must be 30 : 1, and it will be inconvenient to make a wheel large enough to contain the necessary number of teeth, so it is usual to put 60 teeth on the escapement wheel, to reduce the ratio to 15; thus, if the pinion is 10, the centre wheel would be 150. In this case the large wheel and barrel would be the same as in the four-wheel train. Here one circumstance is worth noticing, which is, that the one wheel and pinion will require more teeth to produce the given ratio, than two wheels and two pinions; thus, in the above case, the teeth used are 160, but if we make a train of $\frac{10}{30} \times \frac{10}{30}$, the teeth in use are only 100. The difficulty of using a large centre wheel is now generally got over in these three-wheel clocks, by putting a great many coils of rope on the barrel, by which means the centre wheel is made to turn faster, but it can no longer be used for unlocking and driving the dial work, so another wheel must be made to work into the large wheel for a substitute. If the large wheel turns in three hours, the number of coils must be 64, to go 8 days.

Suppose this large wheel to have 120 teeth, working into another of 40 teeth, and driving also a pinion of 12, then the wheel of 40 will turn once in the hour, and will do for unlocking and so forth. The pinion of 12 will turn in 18 minutes, and a wheel on the same spindle can be used to turn an escapement wheel once in two minutes, without having too many teeth, as the ratio is now only 9 : 1.

It must be observed that this is a better plan than using a large centre wheel, or an escapement wheel of 60 teeth, but the barrel is too long to be put in the clock frame, and must have one to itself.

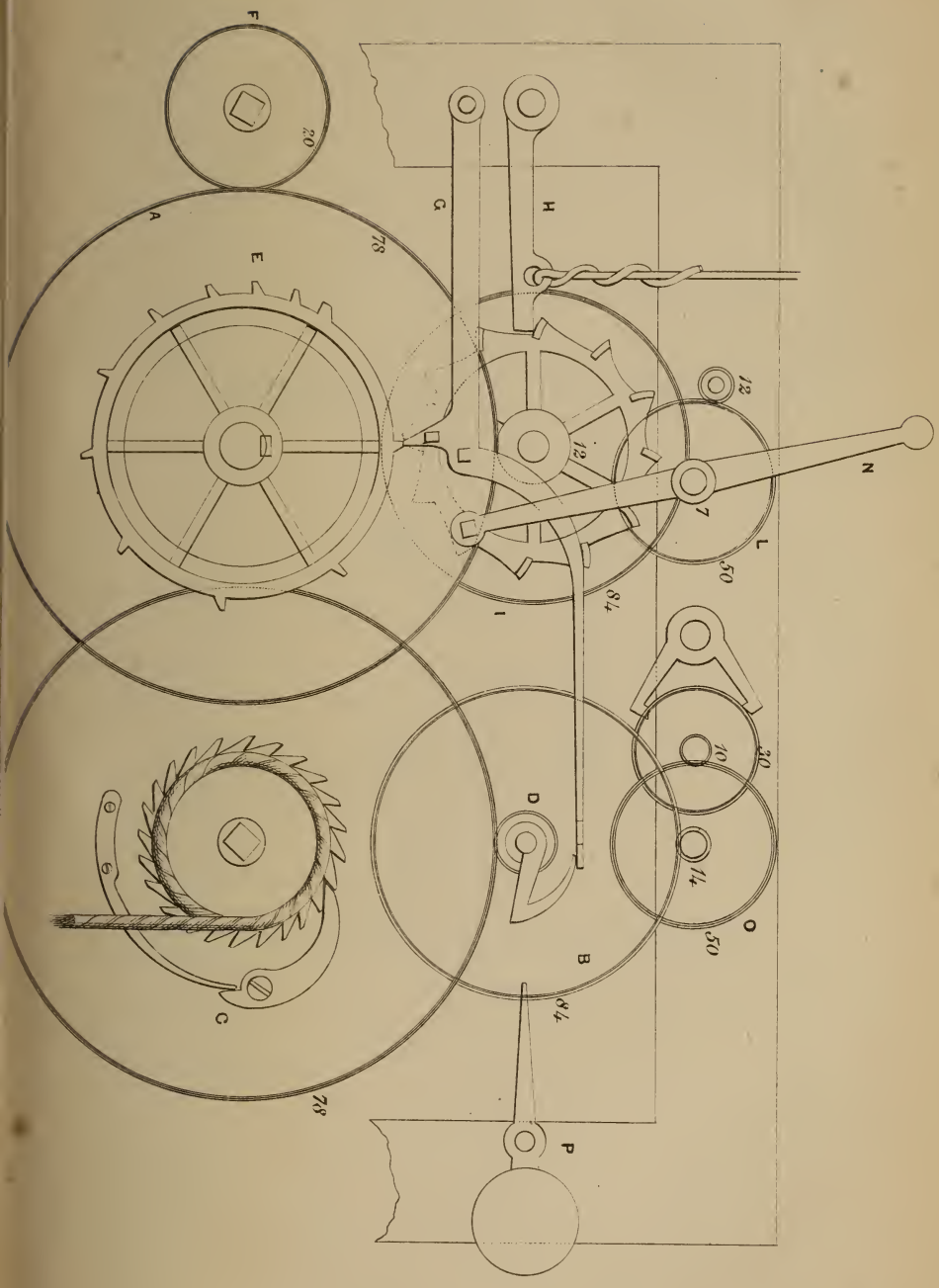
In the striking part of three-wheel clocks, the cams are fixed on the first wheel instead of the second, and this takes much of the strain off the pivots of the second wheel, and thereby reduces the friction. If 78 cams could be put on the first wheel, in would turn as usual in 12 hours, and a barrel of 16 coils would answer, but there is not room enough to contain them, so the barrel must be made to turn in four hours, which will reduce the number of cams to one-third, or 26; and the coils in like manner, will be 48, instead of 16. The motion of the first wheel is too fast to drive the locking plate direct, as in the four-wheel train, so it must be driven by an extra wheel and pinion, reducing motion in the ratio of 3 to 1. Suppose the first wheel to have 130 teeth, working into a pinion of 10, then the pinion will turn half round at each blow, and if the spindle of this pinion carries a small plate with two notches, and also a wheel of 80 teeth, working into a pinion of 10, on the fly spindle, it is plain that the fly will make four revolutions, and one notch of the plate will pass for each blow of the hammer. The clock is locked by means of a lever, which falls into the notches of a locking plate, and part of the lever then comes in the way of a small spanner, fixed on the fly spindle. When the clock is to be unlocked, a separate lifting piece raises this lever till the small spanner on the fly spindle is set at liberty, and the train now goes on till another similar spanner is caught by a claw on the lifting piece. At the end of the hour, when the lifting piece falls, the other lever falls along with it, and this will stop the clock again, as soon as the small spanner comes round, if the lever is not raised

out of the way, while the fly wheel is making the first revolution. As the locking plate moves too slowly to do this, it becomes necessary to attach a roller (to the lever) which stands in one of the notches of the small plate before mentioned. This plate travels fast enough to lift the lever during the first revolution of the spanner, and before this plate can complete half a revolution, the large locking plate will have moved enough to keep the lever out of the way till the next notch allows the lever to fall and lock the clock again.

It is quite immaterial how you arrange the wheels, or what sort of frame you use, provided you contrive matters so as to be able to remove one wheel without disturbing the others, which is certainly advisable. The frame ought to be finished and put together with all its brackets fixed, before any pivot holes are drilled. Centre lines can then be squared and truly marked on the frame, independent of any inaccuracy in the frame itself; and in putting in the working parts, all distances must be measured from these centre lines. The distances between the pivot holes ought to be made as near right as possible, and fitters cannot always be trusted to do this, so after the frame is put together, you had better mark these distances with your own hands; and I should also recommend you to gauge these distances after the holes are drilled, by means of a trammel with a sliding point, as the holes sometimes get wrong in drilling, and cause a great deal of trouble after a clock is supposed to be finished. I shall now conclude by stating that this paper was written at the request of our worthy President, and if the subject thus introduced is an improper one for this Institute, with him the blame must rest.

A vote of thanks to Mr. Pearce was proposed by the President, and carried unanimously.

TURRET CLOCKS.



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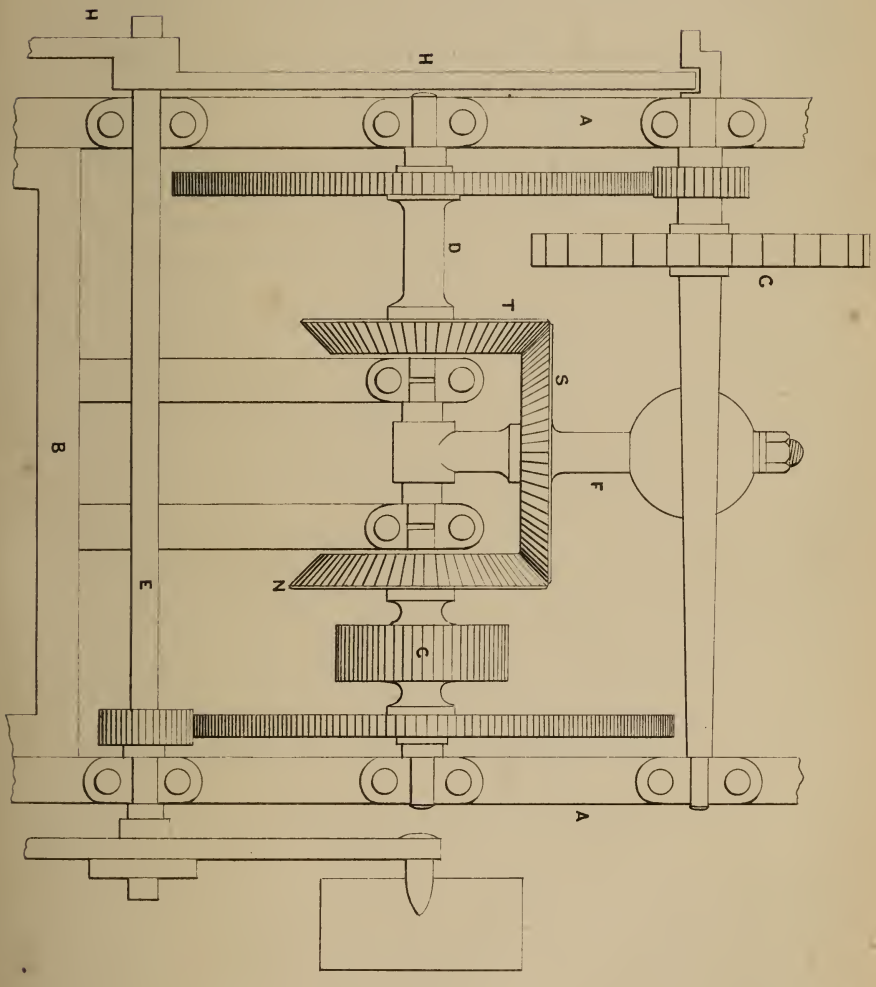

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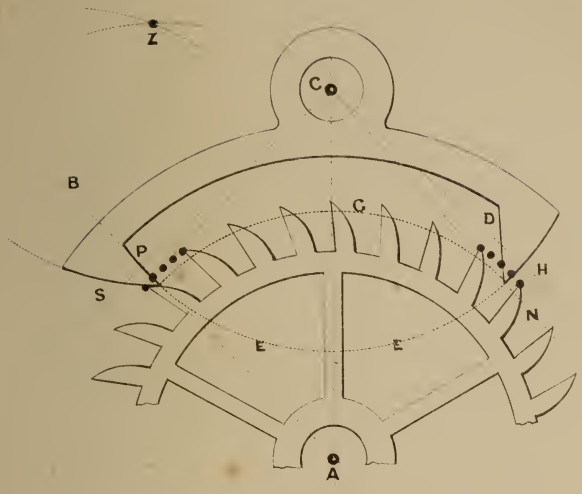

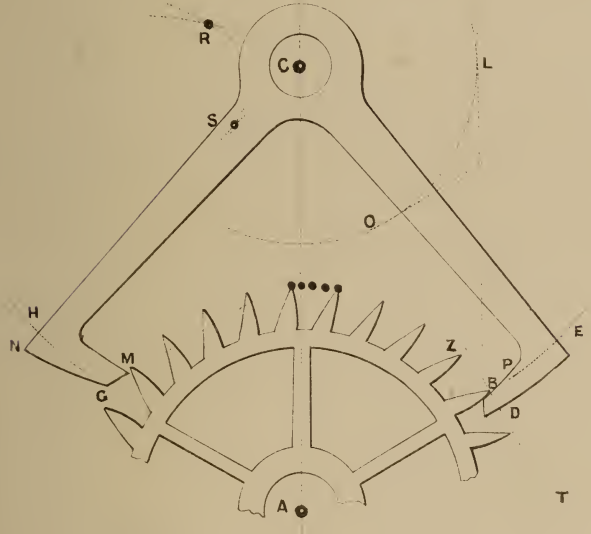

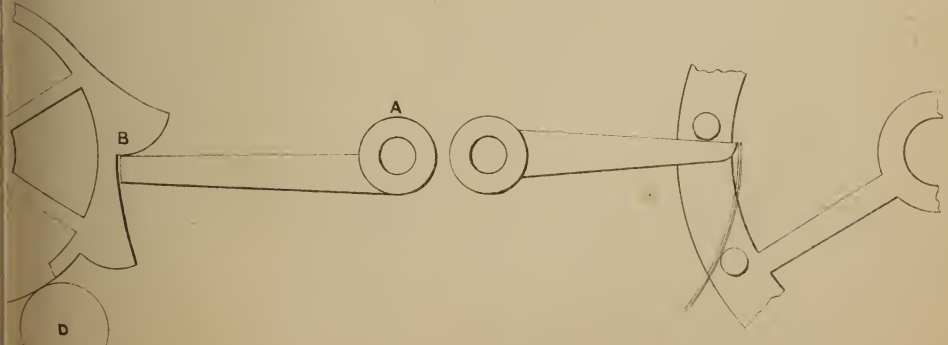

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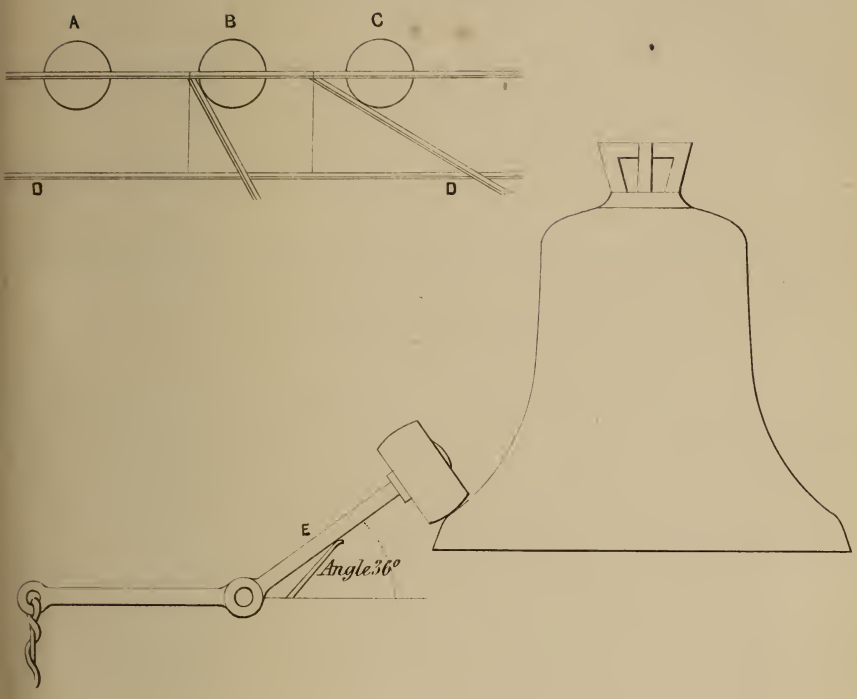
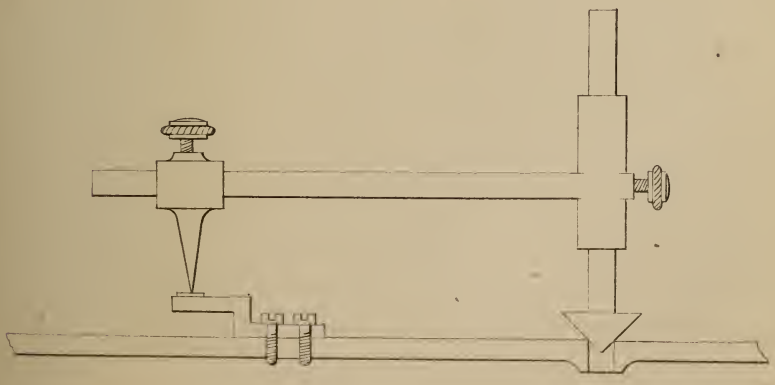


SLIDING TRAMMEL.



Parliament St. London

ON THE
MANUFACTURE OF IRON WITH MINERAL CHARCOAL

By Mr. THOMAS.

Iron, from its use in every mechanical art and contrivance, may be justly termed the great civilizer of nations. It is among the hardest, most common, and most useful of metals. Next to tin, it is amongst the lightest of metallic substances, and next to gold, the most tenacious. It constitutes, according to some, about 2 per cent. of the whole mineral crust of the globe. There is scarcely a rock without iron; but its occurrence in a native state is exceedingly rare. It is fortunate that iron, which is the most useful of all metals, is also the most abundant, and most widely diffused over the world. It is found nearly in every soil, rock, and mineral, combined with oxygen. It is also found in great quantities as a sulphuret, or mixed with sulphur. As a carbonate, it forms the ingredient of many mineral springs. Vegetable and animal structures contain it,—the human body, for instance, where it is believed to exert an important influence in the economy of the frame. Tradition tells us that the discovery of iron was made in consequence of the accidental burning of a wood in Greece, but the art of iron manufacture dates as far back as B. C. 3875, according to common chronology, or 1427 before the deluge. Og, the King of Bashan, had his bedstead made of iron, and some of the Kings of Canaan had their chariots made of iron, which shews that the metal was known in Palestine at an earlier period. The art of tempering steel was discovered by a people bordering on

the Euxine Sea. Since the introduction of Mr. Cort's puddling process, which took place about the year 1783, and which books of some antiquity mention previously, nothing of marked importance has taken place in the history of iron manufacture. A mill for the purpose of slitting iron had been known from earlier times. In an old patent, taken out in 1754, the process of iron making is described as consisting in taking and hammering the iron, and subjecting it to the process of "rolling in a rolling mill." Mr. Cort made, from 60 tons of government ballast, 29 : 3 : 0 : 16, whereas, such has been the gradual but certain progress of improvement in the process of puddling, that with from 27 cwt. to 27½ cwt. of pig iron, a ton of merchant bar iron is produced. Since this, wherever improvements are found, they are traceable to some other science than that on which iron metallurgy is based. chiefly the art of mechanics, not because it is more important, or that iron metallurgy is sufficiently far advanced, but because its supporters have not combined a knowledge of the chemistry of iron with their experience in manufacture, to the degree that the art of metallurgy requires. Dr. Percy says, in his concluding lecture at the Government School of Mines, last session, on the course of metallurgy, when alluding to the imperfect state of the chemistry of iron, "that "there is a wide field of observation and research open to us. We "are told that a kind of iron is good for one purpose, while the other "is bad. We know this to be the case, but have no scientific reason "why it should be so. We find that iron, immersed in cold water, "breaks in many cases brittle: reheated and allowed to cool, it gra- "dually becomes ductile. These are phenomena that point out the "absolute necessity of combining a knowledge of chemistry with "practice in iron manufacture. The egregious losses in puddling, "melting, balling, and hollowfires, cannot but lead us to deplore our "lamentable state, and urge on us the necessity of combining with "our daily practice, a more minute knowledge of the science on "which the art of iron metallurgy is established." These few instances demonstrate the truth of his assertion, and prove beyond a doubt the correctness of his remarks. When we meet, in every corner of the scientific world, with treatises on Geology, and witness

the exertions of its votaries to render the science important and primary, we cannot be but grieved at the apathy of the Metallurgist, who, by no means insensible to the important, and pre-eminent position, he holds in the estimation of his country, and commerce of the world; remains silent, without energy to enforce the object of his ambition and pursuit of his life, to maintain his position in society, and vindicate the dignity of his profession,—a profession, the importance of which is clearly proved by general utility and convenience to mankind, and benefit to the world at large.

The superiority of charcoal iron, over any other malleable iron, has been unquestionable. Charcoal produces a more perfect metallic result than any other fuel used in decarbonization, by shortening the tedious processes of the forge, diminishing the waste, and affording a much more superior quality of iron for all purposes of subsequent manufacture. Charcoal, and puddled iron are fusible, the former at a very much higher temperature than the latter. "The fusibility of bar iron made by the puddling process was easily ascertained, for about the year 1790, William Muckeljohn, in the employment of Mr. Correll, of Leith foundry, obtained from his master a piece of puddled iron, made by Mr. Cort, the inventor of the puddling process, which at that time had created a considerable sensation in the metallurgical and chemical world. This he introduced into one of his pots, and without any difficulty or extra preparation, reduced it into a fluid state, much to the annoyance of Mr. Cort."

At the first meeting of our Institute, Mr. Ebenezer Rogers introduced and explained to the members a process, by which coal could be converted into a substance named "charred coal" or "*Mineral Charcoal*," and which he states would supersede the use of *Wood Charcoal* in the finery. The writer was convinced of the soundness of his discovery, and without loss of time proceeded to test it himself. After making and working a large quantity of this new fuel, the writer finds that mineral charcoal makes much better iron, for the manufacture of tin plate, than that produced from the puddling process, or where wood charcoal is employed as a refining fuel. The substance may with propriety be termed "mineral

charcoal," from its purity, its susceptibility of being penetrated by the blast, its light and porous nature, it escapes, like charcoal, through the chimneys of the refineries, leaving no deleterious matter at the bottom of the fire, to mix with the iron during the process of decarbonization, or on the lump when hammered, or, to use the technical term, "nobbled," or rolled. The iron made from the finer's lump, and after rolling, differs in no respect from iron made with wood charcoal; it is quite as strong and very clean. The charge of pig iron in the metal fire is 5 cwt. One metal fire supplies two refineries, into which an equal proportion of the iron is run. The weight of the coke to the charge is about 4 cwt. in the metal fire. The process continues for about an hour and a half. The measure of wood charcoal to produce a ton of refined iron is about 5½ bags, or about 10 cwt., and may be estimated to cost £1 4s. The weight of mineral charcoal is 10 cwt., which may be valued at 5s., thus effecting a saving, as soon as it will become a permanent adoption, of 17s. on the ton of refined iron. The yield of iron is considered equal from the mineral charcoal. The method adopted for preparing the mineral charcoal is very simple. The coal is cut and filled by the collier, and brought to the works, when, without any previous preparation, except being broken into small, and wetted with water, it is thrown on the bottom of an oven,—the oven being red hot, or at an ordinary coking temperature,—and left there for an hour and a half, during which time the liquid bodies are decomposed, the volatile products are expelled, the carbon becomes fixed, when the hydrogen and oxygen are dispersed. On drawing, it is carefully sprinkled with water, to decompose any remaining sulphur, which now passes off as sulphuretted hydrogen gas.

The writer considers that the chemical composition of the coal used in the process, is a point of great importance. The mineral charcoal used in these experiments was made from a seam of coal locally termed the wing, and has always been celebrated for its superior quality as an iron-making coal. An accurate analysis of this coal has been made in Mr. Rogers's laboratory, by Mr. Wm. Ratcliffe, and found as follows:—

Analysis of Coal.		Analysis of Ash of Coal.	
Carbon	81.13	Alumina	33.45
Hydrogen	4.72	Silica	25.32
Nitrogen	1.03	Sesquioxide iron	11.39
Oxygen	10.12	Lime	16.06
Sulphur	traces	Magnesia	6.60
Ash	3.00	Potash	.96
		Soda	trace
		Sulphuric acid	4.81
		Phosphoric acid	.81
		Loss	.60
	100.00		100.00

The following embodies the result of a week's trial to ascertain the yield of mineral charcoal from this coal:—

	Tons	Tons Cwts. lbs.	
Coal delivered to retorts, 8 : 6 : 0 : 0 of 21 cwt. of 120 lbs.	9 :	6 : 1 : 20 = 20 112	
Mineral charcoal produced	7 :	6 : 0 : 0	
Yield ℔ ton of coal of 20 cwt. of 112 lbs.		15 : 2 : 18 = 78.3	℔ cent. nearly.
Volatile matter lost in charring		4 : 1 : 10 = 21.7	„
Coal required to produce a ton of Mineral charcoal	1 :	5 : 2 : 4 = 100.0	

For my satisfaction I subjected the coal from the same vein to the ordinary process of coking in ovens: time, 48 hours. The following is the result, viz.:—

	Tons		
Coal delivered to retorts, 2 : 17 : 3 : 12			
Coke received	1 : 17 : 2 :	0 = 12 : 3 : 23 = 64.77	℔ cent.
Coal delivered to rabble ovens	5 :	7 : 0 : 6	
Coke received	3 :	7 : 2 : 8 = 12 : 2 : 13 = 63.08	„
Coal to produce a ton of coke	1 :	11 : 2 : 23	

Shewing an increase in the yield in favour of mineral charcoal, of 14.22 ℔ cent.

To guard against error in so unexpected a result, the trials were repeated and found to be correct.

The hollowfire process is the next through which the iron has to pass. Before the introduction of this plan, they were preceded chafferies and ballfurnaces. It was the practice to heat the piles in them, and to attach the staff when hammering. The system now adopted for the manufacture of No. 2 merchant bar iron, was then in use. This is still maintained by Messrs. Banks and Morgan's Broadwater Iron Works, Worcester. The fuel used is coal. The hollowfire is a decided improvement in the manufacture of mineral charcoal iron. Mr. Thomas Baker, Lydbrook, claims the invention of the hollowfire; that designed and built by him was as early as 1798, but others tell us that the present system of working was preceded by a single fire, and that this plan was only an improvement on the pre-existing invention, The plan generally adopted was first constructed for Mr. Partridge, New Weir Iron Works, near Monmouth. These are now taken down. The hollowfires continue to be used in preference to any other plan. The name hollowfires has its derivation from the manner in which the piles are heated. They are not placed on the bottom of the fire, as is the case in balling furnaces, which causes deleterious matter to collect around and beneath the piles, and to combine with the iron in the process of hammering and rolling, but suspended by means of a staff, between the bottom and roof, the workmen taking care that the iron does not come in contact with the fuel. The iron, when finished by the refineries, is conveyed by means of small carriages, to the forge house, being previously sheared to its proper lengths. The width varies from 4 to 6 inches, the thickness from $\frac{1}{2}$ to $\frac{3}{4}$ inch. When drawn through grooves six inches wide, it is almost completely purged of all its impurities. The piles to which the staff is affixed, are about 30 lbs weight. It is then heated and hammered down, when another $\frac{3}{4}$ cwt. is placed on the staff, which is again heated in the hollowfires, and hammered into a slab, and it being cut and doubled, is again reheated and rehammered, and being a third time subjected to the same process, the slab is cut from the staff, and drawn into a bar. The bar when finished is dipped into

water, and is thus divested of its scales, which would be very detrimental to the plates, if allowed to remain. To produce a ton of refined iron, it takes 23½ cwt. of pig iron; and 24 cwt. of refined iron, to produce a ton of finished bars of "mineral charcoal" iron. The metal fire 10 cwt. of cokes; refineries, 10 cwt. of mineral charcoal; and the hollow fires, 14 cwt of cokes.

When the bar is finished it is taken to the black plate rolling mill, where it is sheared to the guage required; that depending on the orders to be executed. Mineral charcoal iron requires less allowance for edges then any other; it is harder, and does not expand as much as wood charcoal iron. The black plate is cleaner, but not so pliable in this process. Each piece of iron is drawn into eight, sixteen, or thirty-two sheets, as the order may require, or the weight of the bar ℔ foot may be. It is then taken to the shearer to cut it to guage, and then to the opener, to take apart the plates from each other. The assorter has then to discard the defective plates, before he passes them to the pickler. The black plate cleans better and with much less vitrol; it is then annealed, and found after this process as tough as any wood charcoal plate. The mode of annealing is simple:—The cases, which are made of cast iron, into which the plates are very carefully piled, are placed in a furnace and remain there ten hours; then passed through two pair of rolls, for the purpose of giving them surface and evenness; then softened in a similar way; after which they are removed to cool in readiness for the pickling room. When pickled, they are scoured with sand and washed in water, placed in a trough, and prepared for the tinning process. With all due deference to the opinion expressed at the last meeting, that they may remain in this state for a fortnight without injury, it is found, since the double annealing was substituted for scaling, that they cannot remain more then two days without causing great injury to the plates, by a substance purging out and streaking them. The tinning process must be considered the most particular to which the plates are submitted. When finished in the pickling room, they are placed in a trough, from which they are taken by the tinman and thrown separately into the grease pot, whence they are placed in the tin pot. The duty of the

tinman is to metal the plate; of the washman, to smooth the rough and uneven surface left by the tinman; of the greaseboy, to improve the surface; of the listboy, to remove the excess of the metal left by the greaseboy on the bottom of the plate; of the rubbers. to clean them in pollards; and the assorter to pick out defects. The box packer packs them in elm boxes, which completes the process.

The quality of iron for the purpose of producing tinplate, has been considered good in proportion to its ductility and fibrosity; but since the abandonment of the scaling process, and institution of the double annealing, it is not of importance; the brittle, close grained, crystallized iron is found to make tinplate equally as pliable, better surfaced, and with fewer defects; and the latter is the kind manufactured from mineral charcoal.

The soundness of the discovery, and the application of mineral charcoal, the writer believes now to be fully proved and established, by practical results, on a large scale: and will soon lead to most important and extensive changes and improvements in the manufacture of iron.

DISCUSSION.

Mr. R. S. Roper, of Pontypool, exhibited specimens of Iron and Tin Plates in the different stages of manufacture, and worked by *Mineral Charcoal.* The very superior quality and finish of these were warmly commended by the meeting. Mr. Roper stated he had been working with the same results as Mr Thomas, and the specimens before the meeting shewed Mr. Rogers' invention to be of great practical value.

Mr. Banks, of Pontymister, stated he had made some experiments with *Mineral Charcoal,* and shewed the meeting some beautifully finished plates of very high quality. The results of his experiments agreed with Messrs. Thomas and Roper. He had also, some years before, tried for Mr. Rogers a series of experiments on this manufacture, and he was the first manufacturer who had really worked the *Mineral Charcoal.* He was at first astonished at the result: he thought *Mineral Charcoal* would quite supplant wood charcoal in the manufacture of iron.

Mr. Ebenezer Rogers stated that he was greatly indebted to Mr. Banks and his late partner, Mr. Thomas Lewis, for the kind manner in which they had worked with and aided him in these experiments. So early as 1850, the tin plates they made as experiments, from *Mineral Charcoal,* were of good quality; but little progress was made; for he (Mr. Rogers) had not then dis-

covered the rationale of many parts of the process. It was within the last two years, and after long and patient investigation, he had found some of the natural laws which governed the work, and from this date, he believed, the manufacture of iron might be classed as an exact science, and no longer necessarily treated as an empirical art. He begged sincerely to thank Mr. Thomas, for the able manner in which he had taken up the subject since the last meeting. As a proof how well Mr. Thomas had understood the work described at the last meeting, he had not expended a single shilling in any unsuccessful experiment, but had at once carried every process successfully through. Mr. Rogers had, at the former meeting, called this new substance "charred coal," but since then he found it possessed the deodorising and decolourising power of wood and animal charcoal, and would be more properly defined under the name of *Mineral Charcoal.* He had no doubt the use of *Mineral Charcoal* would effect great changes in the trade, the hard physical labour of the puddling process was not longer necessary, (and at least one of the aspirations in the eloquent address of their President, Mr. Menelaus, at the opening of this Institute, would soon be fulfilled):—"A process which absolutely costs nearly one half of the value of the material operated upon, to change very slightly its chemical condition,--a large proportion of the cost being for manual labour of the most severe kind, of which the supply rarely keeps pace with the demand, might be economically and advantageously dispensed with."

The PRESIDENT proposed a vote of thanks to Mr. Thomas, for his very interesting paper, which was carried unanimously; and the meeting then separated.

PROCEEDINGS.

21st July, 1858.

The first Annual General Meeting of the Members was held at the Temperance Hall, Merthyr Tydfil, on Wednesday, 21st July, 1858:

Mr. Menelaus, the President, in the Chair.

The President congratulated the meeting on the great success of the Institute. The number of members was now 130, and their progress had been more rapid than the most sanguine promoters of the Institute had ever anticipated.

The Treasurer read his financial statement, and Messrs. Henry Jones Evans and John W. James were elected Auditors to pass the accounts.

The Treasurer (Mr. Brigden) then read the following

TREASURER'S ACCOUNT.

JULY 21ST, 1858.

1858.	£	s.	d.	1858.	£	s.	d.
July 21.—By Cash received from 102 Members	214	4	0	July 21.—To Advertisements	12	19	5
" Cash received from 7 Graduates	7	7	0	" Printing and Stationery	23	9	3
				" Engraving	22	1	8
				" Hire of Rooms	2	14	0
				" Incidental Expenses	2	6	0
					£63	10	4
				Balance	158	0	8
	£221	11	0		£221	11	0
July 21.—By Balance	158	0	0	July 21.—To Cash in the hands of Messrs. Wilkins & Co.	148	5	0
				" Cash in the hands of the Treasurer	9	15	8
	£158	0	8		£158	0	8

(Signed,) HY. J. EVANS.
JOHN WANKLYN JAMES.

The Election of Office-bearers, for the forthcoming Session, was then proceeded with, and the following were elected by ballot:

PRESIDENT: Mr. E. ROGERS, Abercarn.

VICE PRESIDENTS: Mr. W. ADAMS, Ebbw Vale.
" " W. S. CLARK, Aberdare.
" " MENELAUS, Dowlais.
" " THOS. EVANS, Cardiff.
" " GEORGE MARTIN, Dowlais.
" " JOHN P. ROE, Llynfi.

COUNCIL:

Mr. JOSIAH RICHARDS, Ebbw Vale.
" JOHN COX, Newport.
" COPE PEARCE, Cyfarthfa.
" RHYS H. RHYS, Llwydcoed.
" RICHARD BEDLINGTON, Rhymney.
" EDWARD WILLIAMS, Dowlais.
" DAVID ROBERTS, Rhymney.
" TRURAN, Dowlais.
" JOHN JAMES, Blaina.
" DANIEL WILLIAMS, Rhymney.
" HUXHAM, Pontypridd.
" CHRISTOPHER JAMES, JUN., Aberdare.

TREASURER: Mr. BRIGDEN, Dowlais.

SECRETARY: Mr. EDWARD WILLIAMS, Dowlais.

The SECRETARY then read the following paper—

ON THE MANUFACTURE AND USE OF COKE.

By Mr. JOHN COX, Newport.

While metallurgical operations were conducted on so small a scale that the forests were capable of supplying the fuel, the only sort used was the charcoal produced from wood. The reason of this was, not that it was the only combustible known, (for the wood itself was, in its unprepared state, the fuel which supplied the wants of the people for most other purposes,) but because it was found to be capable of producing an intense or concentrated heat at the point to which a blast or current of air might be directed.

Wood, as well as all other substances (vegetable or animal,) which are the result of organic life, is chiefly composed of hydrogen and carbon, two substances which have no chemical affinity for each other in the ordinary acceptation of the term, that is to say, no human knowledge is capable of uniting them to form either of the thousand protean shapes which they assume when united in nature's laboratory of organic life, or in the various substances which result when heat, fermentation, or decomposition, causes the destruction of organic tissue.

Carbon and hydrogen are both combustibles, that is to say, they are both capable of uniting with oxygen. Carbon uniting with one atom of oxygen, and forming carbonic oxyde, or with two atoms forming carbonic acid, while hydrogen unites with one equivalent and forms water. When carbon has united with one atom of oxygen, and formed carbonic oxyde, this compound body is, for the purpose of combustion, but as a simple substance; one com-

pound atom of carbon and oxygen officiating but as a simple atom, and uniting with one atom of oxygen to form carbonic acid: but a compound of carbon and hydrogen, whatever shape it may assume, whether solid, fluid, or gaseous, does not, for the purposes of combustion, act as one body: the affinity of its constituents for oxygen being different, they form a compound combustible in which the affinity of hydrogen for oxygen is perpetually warring against that of the latter for carbon and carbonic oxyde, so that it forms a fuel at all times difficult of management, whether the practical result sought to be obtained is its economic use in the generation of steam, or the concentration of the heat to one point for the melting of metals with that speed which is essential to prevent their oxydation or deterioration.

It is a peculiarity also of the organic union of hydrogen and carbon, that, though it is dissolved by heat, the severance is never direct, immediate, or complete. A part only of the carbon of the solid hydrocarburet is separated under the influence of heat, and the remainder forms, with the hydrogen, many varieties of fluid hydrocarburets, (which, being volatizible, at first assume a gaseous shape,) and of really gaseous hydrocarburets, in which the carbon exists in all proportions, from that containing the smallest trace only, to that in which two atoms of carbon are united with one of hydrogen; in other words, the hydrogen cannot be separated from the carbon of the solid hydrocarburets without taking with it, in a gaseous state, a considerable portion of the carbon itself. When, therefore, we attempt the combustion of a solid hydrocarburet, the first operation is the volatilization of the hydrogen, together with a considerable portion of the carbon; and as it is a fundamental principle that bodies passing from the solid into the gaseous state absorb heat, it follows that a considerable proportion of the heat produced by the combustion of the carbon remaining after the disengagement of the gases, is absorbed by this process of volatilization, and though the hydrogen and carbon, thus volatilized, will, in their combustion, afterwards produce a large amount of heat, which would be available for the generation of steam, for which purpose

the concentration of the heat is unnecessary; still, in metallurgical operations, where the value of the fuel is in proportion to the degree of heat it is capable of generating over and above the melting point of the metal to be operated on, the heat so produced is of no value, as it is produced at a distance from that generated by the combustion of the residual carbon, which is also rendered of less value by having so large a quantity of it uselessly absorbed in the process of volatilization. If, on the contrary, we have to deal with carbon only, its combustion is complete at the point of its contact with oxygen, of which it at once absorbs its full quota or double dose, producing a centralization of the heat at the point at which the blast is directed, thus distinguishing itself from all other combustibles by its perfect adaptation to the requirements of the metallurgist.

In the smelting of iron, to the manufacture of which it is proposed to confine this paper, the use of a pure carbon as fuel is of the first importance, not only because its capability of giving an intense and concentrated heat is in proportion to its freedom from volatilizable substances, but because many of the impurities sometimes found united with it, such as sulphur and silica, are capable of uniting with and injuring the iron; and as the carbon prepared from wood was free from the first of those impurities, the metal produced by its agency was of superior quality. So much has this superiority been acknowledged, that it has originated a belief that charcoal possesses, in itself, some purifying faculty, which is effective, if used even in any of the after processes; a belief which, though founded on the fact that metal so treated is improved, is nevertheless erroneous; the truth being that the carbon is incapable of any such action, the heat and oxygen applied in the process being the sole agents in separating the silica, sulphur, and phosphorus, from the latter of which impurities the charcoal being free, it does not replace a portion, as an impure fuel would, of the quantity of which the process had purified the metal.

When the falling off in the supply of wood rendered the discovery of a substitute for it imperative, pit coal naturally presented

itself for the purpose. That science was then in a sufficiently advanced state for the practical ironmaster to have been aware that its combustible ingredients were the same as those of wood, and that a similar treatment of it should produce a fuel possessing the same attributes, seems scarcely probable; but it is certain that the idea of charring it in the same way naturally occurred, and in the early stage of the successful manufacture of iron by pit coal, it was treated in precisely the same way, being charred in the open air. The result was the manufacture of iron certainly, but of iron of such inferior quality, as compared with that made from charcoal, as to support the idea that the latter possessed some property unknown to the charcoal from coal, and the want of which must necessarily cause the iron smelted by the latter fuel to be of inferior quality; so that the idea of improving this, the first operation in the manufacture of iron, by the improvement of the fuel, appears never to have been entertained: on the contrary, as the process of charring did not appear to produce any or but little improvement in the quality of the iron, attention was directed to the possibility of discontinuing it altogether, and of using the coal raw in the furnace, which being successfully accomplished, the great apparent saving was realized of the cost of coking, and the actual gain achieved of affording a fine field for the exercise of science to invent and improve the after processes necessary for purifying the iron from impurities it never ought to have contained. Up to this time the Welsh ironmaster had never attempted any improvement in the mode of coking, if we except two or three miserable attempts at coke ovens; but the introduction of coke for railway purposes having directed attention to the mode of coking by ovens, they have since been largely introduced into the Principality; not however for the purpose for which they were invented, that of improving the quality of the coke, but of conglomerating together the dirty small coal, which otherwise must have been thrown away. By this means another apparent gain was affected, and the process so completely diverted from its purpose, that its original object was forgotten, and few now seem to be aware that it should be the puri-

fication of the fuel; in fact so completely has the idea obtained, that the process called coking is only for the purpose of enabling the use of refuse small coal, that by many the idea of coking the large to enhance its power and lessen its impurity, will, at first, be received with derision and contempt.

Had the chemical fact been duly considered, that coal, like wood, is a hydrocarburet; that the residuum of a perfect destructive distilization would, in both cases, result in the production of the same substance carbon, which, being a simple body, can possess no difference of quality, except as to the nature of the foreign substances with which it may be associated, it is scarcely possible that any means would have been left untried of so purifying that obtained from coal as to enable it to produce that great desideratum, an Iron of the same quality as that made with charcoal, (which it must do if it be made as pure as charcoal), instead of continuing to make whatever sort of iron ill-burnt coke or raw coal would produce, to be purified by after costly processes to the improvement of which attention has been alone directed.

When the mind has once satisfied itself that the residuum of the destructive distillation of coal and wood is the same substance—carbon; that this is a simple body which cannot vary in quality; that the carbonic oxyde produced from the one must be the same as the carbonic oxyde produced from the other; that the carbon given to the iron by the carbonic oxyde of the one cannot vary from the carbon given by the carbonic oxyde of the other; it arrives at once to the conclusion, that it is to the different foreign bodies alone with which the carbon of coal is allied, that its inferiority is due; and the inquiry then naturally arises, what the nature of these may be, and whether they can be got rid of, or rendered innoxious.

Chemical analysis shows us that coal contains, as impurities, silica and sulphur, and as constituents capable of being volatilized, (bodies whose evolution in the state of vapour operates to prevent the concentration of the heat, as has been before shewn), hydrogen and oxygen.

In order to judge of the injury which the impurities of coal cause, we must first understand their operation during its combustion in the furnace.

If we consider the operation of the blast furnace, commencing at the top, we see that the iron ore, after being heated by the spare heat of the ascending gases, passes slowly down through the heated mass, absorbing carbon from the carbonic oxyde, until the whole of the oxygen the ore contained has been absorbed by the carbon, and until the metallic particles have taken up such an excess of carbon as is necessary to enable them to separate themselves from their earthly base and assume the metallic form, which they do when they reach the zone of fusion, or that part of the furnace where the temperature is above the melting point.

If we consider the operation, commencing at the bottom, we find that the carbon is, in the zone of fusion, or that part immediately above the tuyeres, converted into carbonic acid; thereby generating an intense heat, of which a portion is imparted by the ascending gas to the upper strata, preparing them for the chemical action about to be described. The carbonic acid acting on a portion of the carbon so heated, imparts to it one atom of its oxygen, and carries it off as carbonic oxyde, to which state it thereby also reduces itself. The carbonic oxyde thus formed relinquishes one atom of its carbon to the oxygen of the iron ore, thus reverting to the state of carbonic acid, to be again reconverted to carbonic oxyde by the surrounding heated carbon. This process goes on continually in its passage up, until, near the top, becoming too cold for acting on the ore, it escapes in the form chiefly of carbonic oxyde.

Of the solid impurities contained in coke, sulphur, which has a great affinity for metallic iron, immediately seizes it in the zone of fusion, and it is scarcely possible to conceive that, if present, its injurious effects can be avoided; but it is scarcely necessary to discuss this question, as it is possible almost entirely to free this fuel from it, if, as is the case with the very pure coals with which the Welsh mineral basin abounds, it does not exist in it in too great a quantity. For the few seams of coal of a different nature, suffi-

cient uses can be found for other purposes to render it a matter of little importance whether they can be so purified or not, though, as far as the writer is yet aware, there has not been sufficient experience of the process about to be recommended on these coals to enable us to say to what extent they can be so purified.

The action of steam in desulphuretting ores has long been known, and its application for the same purpose to coke admits of but one difficulty besides its cost, the continuance of it for a sufficient time while the coke is at a red heat. If the coke be drawn red hot, and water poured upon it, the evolution of sulphuretted hydrogen is perceptible in the steam, but the small quantity of water which can be used, on account of the rapid cooling of the coke, prevents it operating to any sensible extent, as may be seen, if the coal contained much sulphur, by exposing this coke afterwards to the action of atmospheric air and moisture, when it becomes stained in consequence of the decomposition of the sulphuret of iron still remaining in it. If the coke be steamed in the oven with steam, at a high temperature, the mass of coke might remain red hot for a sufficient time for its purification, but as it would be necessary to admit the steam under the body of the coke to insure its passage through it, the practical difficulties, as well as the cost, induced the writer to seek whether a simpler process could not be discovered.

That steam, in its evolution, will carry off sulphur as sulphuretted hydrogen, there can be no doubt, as that it does so when the coke is cooled *en masse* outside the oven, is evident to the senses, as before stated; but, that if the process stopped at the point at which the heat ceases to convert the water into steam, (as is then the case,) a considerable quantity of it would remain in a state capable of being *washed* out, is a fact which was prominently brought to the writer's notice some years since, by the rapid destruction of the copper balls of ball cocks floating in water in which a small quantity of such coke was immersed, and which originated the idea that if the coke was first cooled in the oven, and then, after being so cooled, a sufficient quantity of water was poured in,

thoroughly to wash it, to run, in fact, through it, and pour in a stream out of the oven, we should nearly accomplish its thorough purification.

This anticipation has not been disappointed in practice, and it is found that when the oven is worked at a very high temperature, a large quantity of water (estimated at two tons for every ton of coke it contains,) can be poured into it without injuring the after action of the oven, or preventing its retaining sufficient heat thoroughly to dry the coke before it is drawn.

Cooling the coke by water thrown on it inside instead of outside the oven, having long been practiced in the North of England, to reduce the temperature of the oven, and facilitate the process of drawing the coke, (although the plan has been generally discontinued in consequence of its injurious effects upon the oven,) the practicability of so doing was established, and it became only necessary to construct the oven of such a material, and in such a manner, that the cost of its repair should be kept within the bounds of moderation, and to work it at such a temperature that the heat of the mass, at the moment the water is poured in, should be sufficient to allow of the application of a very large quantity of it.

This first-named difficulty appears to have existed more in imagination than in reality: the judicious application of known refractory bodies easy of attainment, (viz., silica and pure fire clay) in different proportions, for the formation of bricks to suit the various degrees of heat to which the different parts of the oven are exposed, will enable the architect to build an oven capable of resisting, for a considerable time, the combined action of the heat and water; and if proper arrangements are made in its construction for facilitating its repair, the cost will be but trifling as compared with the great advantage gained.

Silica, the other solid impurity in coal, which is of a nature neither soluble nor volatilizable, enters so minutely into its composition (as it formed a portion of the plants of which it was composed,) as to prevent the possibility of its separation. It follows, therefore, that if this impurity must necessarily be imparted to the iron, the

value of the coal is immensely deteriorated by it. The affinity of silica for iron, in its metallic state, is very small as compared with its affinity for its oxyde, for which it is so great that the process of the purification of iron from it consists in oxidating a portion of the iron, which immediately separates the silica from the remainder, and unites with it in the form of slag. Referring to the action of the high furnace, it, therefore, becomes evident, that the more perfectly the ore is deoxidated, and the more highly it is carburated, the more completely it must be separated from its silicious base, and the purer from silica the iron ought to be; a self evident truth strangely at variance with the fact that grey iron, iron the most highly carburated, invariably contains the largest amount of silica. It has ever been supposed that the silica in pig iron has its origin in the ore from which it is produced, but as it is impossible to believe this, consistently with the knowledge that it is the deoxidation and carburation of the ore which separates it from its silica, and account for the fact of the greatest amount of silicia being found in the most highly carburated iron, it is difficult to avoid the conclusion, that the iron, if properly carburated, is thoroughly desilicated in the zone of carburation, and takes up silica again in its passage through the zone of fusion; in other words, that the silica found in grey pig iron is derived from the fuel, and not from the ore; in which view we are supported by the fact, that those irons which, being highly carburated, contain most silica, are the longest in passing through the furnace, and, consequently through the zone of fusion. The charcoal of wood contains an amount of ash often in excess of that contained in many of the Welsh coals, and the per centage of silica in the ash is also larger; yet, although the rule, that the amount of silica in the iron is in proportion to its carburation, holds good with that made from charcoal, as well as with that made from coke, still the quantity in each sort of charcoal iron is less than in the same sorts of coal or coke iron. This second paradox which, at first sight, appears to militate against the view of the writer as to the origin of silica in iron, is easily explained, if we consider that silica, in the form of glass, as it exists in the cinder of the high furnace, has no operation on iron, and that the lime and

potash existing in the ash of charcoal, is sufficient to flux the whole at a very much lower temperature than the ash of coal (which contains so small an amount of lime to flux it,) will yield to.

Believing this difference in the fusibility of the ash, to be the real cause of the extra quantity of silica found in coke iron, the writer deemed that a remedy for the evil would be found in increasing the combustibility of the coke, and thereby effecting the fusion of the ash.

In order thoroughly to comprehend this proposition, we must understand that in the high furnace, combustion, properly so called, takes place only in the zone of fusion, where the oxygen of the air first meets and unites with the carbon of the fuel, which zone is, as has been already described, extended or diminished according to the capability of the fuel for rapid combustion, and that, the quantity of heat being in proportion only to the air blown in, it follows that its intensity must diminish as the zone of fusion is extended, and increase as it is diminished. Above this zone, combustion, or the creation of heat, not only absolutely ceases, but the caloric produced in it is absorbed in the process of heating the mass of materials above it; and also, and to a much greater extent, in the process of reconversion of carbonic acid into carbonic oxyde; which, although it carries off a great amount of carbon, is the reverse of combustion, being the conversion of a solid body into a gaseous form, and of a heavy gaseous body into a lighter one; the heat of the furnace, therefore, above the zone of fusion, not being sufficient to reduce the iron into a metallic state, cannot consequently effect its union with the silica of the fuel. In passing through the zone of fusion, if the heat be not sufficient to have fluxed the components of the ash into a glass before the iron comes into contact with it, it is but fair to conclude that an union between the iron and the silica would be the result; but if they be instantly converted into the form of glass, all experience would lead to the conclusion that no such union would take place.

Some circumstances which fell under the writer's personal observation, led to the conclusion that this great desideratum, the pro-

duction of a coke of great combustibility, could be readily obtained, and as their singularity made a deep impression on him, and led to the researches which have resulted in this paper, it may not be amiss to relate them here. He once had occasion to show to a friend, the proprietor of a colliery of justly esteemed steam coal, a large piece of glassy clinker, portion of a layer which had been formed entirely over the fire-bars of a locomotive, from coke made of his coal, and he well recollects his friend's vehement expression of astonishment and incredulity. He afterwards, (considering the coal useless for making locomotive coke), offered to sell it to another friend, a glass maker, at a heavy loss, to get rid of it, and he was much surprised at the irritation of this friend, (when refusing the offer, after trying the coal,) arising from the loss and annoyance it had caused him because it would not clinker on the bars, a quality essential to the manufacturers of glass, being the only means they possess of damping the fires when the process of founding is complete. The other instance which occurred, after a more extended experience had given a clue to the phenomenon, was, that in the fire-box of a high pressure boiler, in which steam coal, when burnt, produced little or no clinker, coke made from the same sort of coal, much more carefully cleaned, and made into coke under the writer's personal inspection, burnt with such intensity as to melt the whole of the ashes on the bars into a greenish glass. These results appearing clearly to demonstrate that the coke in question had acquired a combustibility, not only superior to that of the coal from which it was made, but also to that of ordinary coke; and having established the fact of the feasibility of imparting this quality, it became requisite to ascertain its cause, and as it was evident that this could be nothing else than the complete separation of the volatilizable compounds, there remained nothing but to discover the means of effecting this, to insure the accomplishment of this desideratum.

The first of the volatilizable components, hydrogen, is easily separated by the application of even a moderate degree of heat if applied for a sufficient time, and the only effect on it of increasing the temperature of the carbonizing process, is to shorten the operation,

and prevent the hydrogen carrying off with it so large a quantity of carbon; for the organic union of hydrogen and carbon being dissolved by heat with a rapidity and completeness proportionate to its intensity, it follows that the quantity of carbon carried off is in an inverse ratio, and that of the carbon remaining, or, in common parlance, of the coke produced, (if the operation be conducted without waste,) is in direct proportion to the heat applied. If, therefore, the only effect of the coking process were the separation of the hydrogen, little doubt can be entertained that, in a high furnace in which raw coal is used, this process is completed far above the zone of fusion. Whether coal so coked in the furnace, under the pressure of the other materials, does assume a sufficiently dense or crystalline structure to enable it to reach the zone of fusion in the best form, need not now be discussed, because it is the intention of the writer to show that there is another volatilizable substance to be got rid of, whose affinity is too strong to be acted on by any degree of heat contained out of the zone of fusion. This substance is the oxygen, the evil effect of which appears as yet most strangely to have escaped the notice of the scientific world—until of late years the presence of this substance was unsuspected—the earliest observation which induced a suspicion of it appears in Mushet's Work on Iron, in which is an account of an experiment with an Anthracite, which, after being subjected to the usual temperature for driving off the hydrogen, in which it lost only eight per cent., lost ten per cent. more when subjected to a temperature of 178° of Wedgewood.

It is somewhat singular that so strange a phenomenon did not lead so acute an observer to investigate it, in which case the presence of oxygen must have been detected; but its existence as a component part of coal appears not to have been suspected until it was accidentally discovered by the finding of carbonic oxyde on analysing the gas produced, by the distillation of anthracite at a great heat in a laboratory, and, in another part of the kingdom, by the unintentional manufacture of carbonic oxyde from coal under the following circumstances. The engineer of a large gas works being called upon to supply gas for inflating a balloon, (being "with an economic spirit blessed," and being also sufficiently acquainted

with gas making to be aware that the gas produced, during the latter part of the process, possesses but little illuminating power, which he naturally concluded to be due to the greater heat, then separating the hydrogen almost free from carbon,) conceived the idea of separating the illuminating gas produced in the early part of the process for the purposes of illumination, and then passing off the poorer gas of the later part into a separate gasholder for inflating the balloon.

This gas, which, if it had been the hydrogen he expected would have been extremely light, proved, on the contrary, so heavy, that the balloon would not rise, a phenomenon which chemical analysis afterwards explained by discovering that it was carbonic oxyde. Since then the presence of oxygen in coal has been acknowledged, but the important part it plays is so little appreciated, that, up to the present time, as far as the writer is aware, its quantity is not ascertained in analysis by any thing but the amount of loss, and it is often also included with the nitrogen. By most chemists it is supposed to exist in coal in the shape of water, in which case it would pass off as steam, carrying with it its quota of hydrogen. If this were so, (supposing that it resisted the application of ordinary carbonising heats, and passed with the coke into the zone of fusion, which we know it must certainly do whatever it be allied with, in consequence of the great heat necessary for its disengagement,) its effect would be sufficiently injurious; but if, on the contrary, it exists in the coal united to the carbon, or, at all events, not in union with hydrogen, (which the foregoing incidents and many experiments have sufficiently established), so that it cannot be made to leave without carrying with it its equivalent of carbon, it follows that with every 1 per cent. of it, must be volatilized .75 per cent. of carbon, and, therefore, for every 4 per cent. of oxygen contained in the coal not only is 7 per cent., of what is supposed to be fuel, rendered useless, but it requires the combustion of a large amount of real fuel to dispel it. Although oxygen, where it exists in the gaseous state in the atmosphere, is the means of creating heat, whether, as is the theory of many philosophers, by rendering its latent heat sensible in consequence of its being as it were squeezed

out of it during the process of its condensation from its higher and more expanded volume as oxygen, to the more compact and dense form of carbonic acid; or whether the heat so created be as other savants think, owing to some yet unexplained effect of its union with another body. Still it is clear that the oxygen in the coal cannot be a heat creating substance, as it already exists in union with the carbon, as is proved by the fact of its passing off as carbonic oxyde, and of its requiring the application of a most intense temperature to enable it to do so. That the effect of this body on the combustibility of the coke must be very great, became, therefore, so evident, that there could be no difficulty in attributing the greater combustibility of coke, when prepared at a great heat, to its having been thereby deprived of its oxygen; and the writer arrived at the conclusion that the attainment and maintenance of this heat, during the process of coking, is alone necessary (by insuring the separation of the oxygen) to impart such a combustibility to the coke as will cause it to flux its ashes before the silica can have effected any injury on the iron.

From the foregoing observations it will be seen that the proposition which the writer advocates is, that the carbon of coal can be rendered nearly as free from sulphur as the carbon of wood, and if the oxygen be expelled, the silica in it can be rendered innoxious; and that to effect both these objects, it is only requisite that the process of carbonization be conducted at an intense heat, which must be maintained, for the purification from sulphur, as high as possible to the completion of the process, to enable the application of a greater quantity of water. It remains then only to explain how this intense heat is to be produced and maintained. It is well known that the heat used in the process of coking is created by the combustion of the volatilized components of the coal, and it can only be increased (unless by a consumption of the carbon) by economy in their combustion. This economy is to be attained by attention to the construction of the ovens, by the skill exercised in the charging and management of them, and by the purification of the coal.

Although the form of the oven is necessarily a consideration of the first importance, particularly where the quantity of bitumen in the coal, is so small as to render the obtaining the requisite amount of heat a subject of difficulty; still it must not be supposed that it is the all essential point, a belief in which invariably leads to disappointment. The more perfect the machine the more skill is required in its management, and in bad hands the best ovens will produce the worst coke. It will be sufficient, in discussing this part of the subject, to observe only, that the oven must be constructed so that the draught may be capable of easy regulation; of a material which will resist an intense temperature and the action of the water; and of sufficient solidity to prevent the rapid radiation of the heat.

As the heat of the oven depends upon the combustion of the gases evolved, it follows that we must devote our attention to promote, first, their evolution, and afterwards their combustion. To effect the first, it is necessary to observe that the heat is produced above the coal, that the coking commences at the top and proceeds gradually towards the bottom, so that towards the latter part of the process it has to penetrate down through a large layer of a non-conducting substance. As the process proceeds, the coke forms itself into a mass of imperfect columnar crystals, through the interstices of which the heat is enabled to penetrate, and the gases evolved from the coal rise to the surface. On this crystalization depends the due working of the process. If any foreign solid substance be mixed with the coal, it acts mechanically to prevent crystalization, and, by so doing, obstructs the action of the heat on the lower portion of the coal; the evolution of gas consequently diminishes, and, with it, the heat of which it is the creator and supporter, and the result is that the oven does not maintain, if it ever attains, the requisite temperature. No care or skill in the management of the process, nor any superiority in the form or construction of the oven, will counteract this evil. To do away with it by the separation of the coal from all foreign substances is the only means of overcoming it. The writer dwells on this point because many cannot conceive

why he should be at such pains to clear the coal from shale, while this substance is often put with the coke into the furnace to flux the base of the ore; and he wishes it to be distinctly understood, that it is not from fear of its effects in the furnace that he is so careful to separate it from the coal, but only because its presence in the oven would prevent his obtaining that heat in the process of coking, he deems so essential to the purification of the coke from the two most injurious constituents of coal—sulphur and oxygen; the entire absence of which would render it equal if not superior to charcoal of wood.

To promote the continuous evolution of a sufficient supply of gas, to maintain, by its combustion, the temperature of the oven, it is necessary that the coal be so charged, that it shall work off at all parts of the oven at the same time; as, if this is not the case, either the coke will have to be kept in the oven after most of it has been worked off, until the part improperly charged be ready, (and the production of gas being then but very partial, the oven will rapidly lose its heat;) or otherwise in order to retain the heat of the oven, it must be drawn before the coke is cleared, and with raw coal under some part of it. Of these evils, although it is usual to choose the former (as the want of care in the workman will not be so patent to the eyes of his employer), it is decidedly the worst to adopt, as it will require many days to regain the heat the oven has lost; while the effect of the water as a purifier from sulphur will be materially lessened. Having provided for the evolution of the gas by cleansing the coal to promote the crystalization of the coke; and being in possession of an oven capable of regulation, built of a refractory material and proper solidity, we have only to consider the management of the process with a view to produce the greatest amount of heat from the combustion of the gas alone, and to maintain it as high as possible to the moment of drawing. It is obvious that this object is to be attained by so regulating the oven that the quantity of air admitted shall be sufficient for the combustion of the gas, while, at the same time, it shall not be in excess. If it be not sufficient for the purpose, it is clear some portion of the gas must

pass off unconsumed; it will have absorbed heat in its volatilization and given out none by its combustion, thereby cooling the oven. If, more be admitted than is required, it not only tends directly to cool the oven, but it burns away a portion of the coke, the ash of which, obstructing the radiation of the heat, indirectly prevents its creation by lessening the supply of gas.

It is a very commonly received opinion that coke, burnt at a great heat, must be hard and difficult of combustion, which has given rise to a desire among furnace managers for the acquisition of a coke burnt at a low temperature. This opinion which it will be seen is in direct opposition to the writers views, has arisen from a misunderstanding of a phenomenon which takes place in coking bituminous coals, without reference to the heat at which the operation is conducted, if the process be sufficiently prolonged. This is called hardening the coke, and usually takes place after the third day; it consists of a rounding of the edges of the crystals of the coke, a filling up of its pores, and a general hardening or toughening of the mass; and may be considered to be due, either to a change in its crystalization, or to the condensation of a portion of the carbon contained in the highly carburated hydrogen arising from the coking of the lower strata; or more probably to both of these causes combined. Its effect is to present a considerably smaller surface of the coke to the action of the oxygen, and, consequently, to prevent that rapid and concentrated combustion so strongly insisted upon by the writer, for the purpose of fluxing the ashes of the coke; it is, therefore, to be avoided as much as possible in the manufacture of coke intended for the smelting of iron. The more bituminous the coal, the more rapidly and completely the coke hardens; this, therefore, determines the length of time which the process of coking ought to occupy; for as the longer the operation, the larger is the crystalization, it is advisable that the time employed shall fall short only of that when the hardening process would commence. Except, however, in the highly bituminous district east of the Tredegar Valley, there are but few of the seams used at the Welsh Iron Works, which are capable of acquiring this hardness to any injuri-

ous extent, and it does not require much observation even with those coals to enable us to avoid it.

To many of those engaged in the manufacture of coke, these remarks may appear unintelligible or superfluous. In the manufacture of railway coke, the skill (if skill it can be called) of the maker consists in finding a coal which is sufficiently free from sulphur, and which will coke easily, that is to say, which is free from extraneous matter, and contains the requisite amount of bitumen. In each of the coal basins of England and Wales, one or more seams are found possessing those characteristics, and they have been distinguished by the name of coking coals. To make of these a good looking and marketable coke is a matter of no difficulty; but the great mass of the mineral wealth contained in the coal seams of the Welsh mineral basin, do not possess the last of these characteristics. Nature has half performed the process of dissolving the union of hydrogen and carbon, so that when heat is applied, the hydrogen passes off comparatively free, the quantity of combustible gas evolved (to be used in the production of heat in coking) is comparatively small, as is also the quantity of carbon existing in union with the hydrogen in that proportion which forms bitumen, and promotes the crystalization of the coke. To coke these coals, therefore, is attended with so much difficulty, that nothing but the certainty that the doing so is essential to the developement of their value, would induce us to endeavour to overcome it.

It is a commonly received opinion, that the superiority of any mode of coking is to be estimated by the large per centage of coke produced; and it may be so in the eyes of the makers of coke for sale, but in the maker who consumes it, it is a grave error, as it tends to the manufacture of an inferior quality. If there were nothing but hydrogen to be expelled it would be correct, as it would show either that this body had been volatilized in conjunction with a small quantity of carbon, or that but little of what should be residual carbon had been wasted in the process; but if fixed oxygen has to be acted on, which must also carry off with it the carbon with which it is united, the fact of what appears to be residual car-

bon, being in excess of what should remain after the expulsion of this body, is sufficient to prove that the process is incomplete.

If we take a coal, which, distilled in a close vessel, at an ordinary carbonizing heat, would produce 80 per cent. of coke, it would, if 4 per cent. of fixed oxygen be driven off, lose 7 per cent. more, and, if we allow 5 per cent. for braize and waste, we should obtain 68 per cent. of coke, which is the average quantity that, with such coal, the writer has found can be calculated on.

The difficulty of saying how much of the oxygen exists in coal as fixed oxygen—that is, united with carbon instead of hydrogen; from the great heat necessary to evolve it, requiring a retort capable of enduring a temperature which it is doubtful if even platinum would resist, has prevented the writer from satisfactorily solving the problem of the loss to be attributed to its disengagement. The proportion of fixed oxygen doubtless varies very much in different coals, and to its absence in some may be attributed their known superior strength when used raw in the furnace, over others of very similar composition, which can be accounted for in no other way; but whatever it may be, its presence is so injurious that its absence should be secured, even by what may appear to be a sacrifice of coke.

To the ironmaster the question is, not what per centage of coke he can produce from the coal, but how much coal the process will enable him to dispense with in making a ton of iron; and if, as the writer's experience authorises him to assert, this will be from 10 to 15 per cent. of what the same furnace would use to make the same description of iron, it matters nothing what per centage of coke the coal produced, and but little what was the extra cost of its production.

This necessarily brings us to the next consideration, the cost of the process, and here it is as well not to disguise the fact, that, when using the semi-bituminus coals of South Wales, the comparison to be made is between the economy of incurring the cost of properly coking large coal, and of using it raw in the furnace, and not between it and the cost of the ordinary coking of dirty small coal,

which the writer believes might be more advantageously thrown away. The cost, therefore, to be estimated will be the total of preparing the coal, of coking, repairs, and interest of capital.

The coking and filling will be the same as in the ordinary way, tenpence per ton; the preparing the coal, repairs, and superintendance, may be set down at the like amount; and if interest of capital be taken at fourpence, the total will be two shillings per ton. This, the visible saving effected of fifteen per cent. of coal would, in most cases, nearly cover, and there then remains the value of the other savings and advantages to be ascertained. These are, first, extra make of the furnace twenty per cent. and, second, saving in iron in the after processes of refining and puddling, in consequence o its comparative freedom from sulphur and silica. This, of course, refers only to the manufacture of pig, for making bar or rail; but in the manufacture of foundry iron the value of the process future experience alone can ascertain; suffice it to say, that as far as the writer's experience has gone, he believes he is justified in stating, that if iron be smelted with coke so made, the rule that the most carburated contains the most silica appears to be reversed. The only time he had an opportunity of seeing this description of iron so made, it (in addition to its comparative freedom from sulphur) contained, not only less silica than white iron, but also less than is usually found in any variety of charcoal iron.

DISCUSSION.

The PRESIDENT complimented Mr. Cox on the very able paper just read. Mr. Cox, he believed, had paid more attention to the manufacture of coke than, perhaps, any other man in England, and his opinions on the subject were of great value. Pure fuel, produced cheaply, would, no doubt, be of immense advantage to the iron trade, as a means of improving the quality of the iron. Mr. Cox seemed to think that this depended solely on the purity of the fuel; it was well known, however, that the character of the ore used, had much to do with the quality of the iron produced. There were present several men of great practical experience, and likewise several who had made the chemistry of the manufacture their particular study; he would be glad if some of these gentlemen would give the meeting the benefit of their experience.

Mr. RILEY said that Mr. Cox's paper was so voluminous, and involved so many important matters, that it required great consideration, and he had

scarcely been able to follow him. There were two points he would notice. Mr. Cox had stated that the quality of iron was greatly influenced by the kind of fuel used in smelting, and appeared to consider it as the only cause of the difference of quality; but this was not the case, though the coke had a decided influence. He had lately seen tried ores containing a large per centage of silica, as quartz or sand, and the result was a very siliceous iron, containing, in one case, in white iron, $3\frac{3}{4}$ per cent. of silicium. It would appear that when silica exists *per se* in any quantity either in the fuel or the ore you will have a siliceous iron; but when mixed with alumina a more fusible silicate is the result, and it appears to prevent the reduction of the silica, from the fact that all double silicates are more fusible than simple ones, i. e. silica when combined with two bases. It was a curious fact, that iron containing silicium always had a very smooth face, and white iron had a peculiar blue colour, like the bloom of a plum. When it contained much silicium, such iron was always very bad and difficulty to puddle. Perhaps some of the furnace managers present would say whether, in their localities, they found the same thing, or whether the instance he gave was an isolated case.

Mr. E. Rogers: from the long experience Mr. Cox had in the manufacture of coke, his opinions were entitled to great respect. Mr. Cox had rightly observed that the quality of fuel used in the smelting of iron was very important. The remarks as to silica in the coke deserved careful consideration, and had hitherto been little noticed. He (Mr. Rogers) had been engaged for some time past upon an investigation of furnace coals, with the object of ascertaining the causes of their different effects in the blast furnace. One of these causes was, no doubt, the quantity of silica in the coke, and this could often, to a great extent, be separated by washing, or carefully selecting the coal. The mechanical structure and hardness of the coke, was also of interest; and often determined its economic value, as fuel, for different purposes. The intense heat produced by the ignition of charcoal and coke, under a pillar of blast, is due to the large surface exposed in a small space to the action of the air. In making wood charcoal, the process of coaling drives off the water and gases of the wood, and thus hardens the substance of which the cells are formed, leaving nothing but a porous mass, formed of a number of small cells or tubes, which allow the blast of air to act upon a very large surface of carbon within a small space, producing a very high temperature from the concentration and consequent intensity of the combustion. It has been ascertained that one cubic inch of beechwood charcoal presents, in this manner, at the lowest computation, a surface of one hundred square feet, and the surface exposed in sound close-grained woods is probably much greater. The hard woods, such as oak, beech, &c., are known to be the best for smelting; in these the tubes or cells are small, and the total surface exposed is consequently larger. The process of coking also in a similar manner converts the coal into a porous mass; but this is done during the melting of the

coal, at which moment the gases in liberating themselves form very minute bubbles; but the practical result is the same as in wood coal, allowing a large surface of carbon in a small space to be acted upon by the blast. As a general rule, the larger the pores the softer the coke, and thus soft porous coke, when used in the blast furnace, is not only crushed in its descent, but, under a heavy pillar of blast, is not decomposed so as to give heat rapidly, or intense enough to carry a heavy burthen on the furnace. The pillar of blast, as is well known, must be proportioned to the character of the coke; a hard coke, with close pores, requires a heavy blast to decompose it rapidly, but this enables the furnace to carry a good burthen and drive well. The quality and quantity of iron made, are so dependent upon the coke used in the furnace as to make the subject one of great interest and importance.

Mr. ROPER was much gratified with Mr. Cox's very able paper on coke, and generally agreed with the conclusions arrived at by that gentleman. He could not, however, coincide with the opinion expressed by the President, that the sulphur found in pig iron was less due to the coke used as fuel than to the iron ores, and he would state the grounds on which he founded his dissent. He had compared the analysis of a very great number of iron ores representing the chief iron producing materials of Britain, and found the average per centage of sulphur in them to be 0.08 per cent. He had also examined about 30 analysis of coke as generally used in blast furnaces, and the average per centage of sulphur was 1.25 per cent, reaching as a maximum about 2.25 per cent. He, therefore, considered himself justified in thinking that the quantity of sulphur usually found in the British pig iron was derived from the fuel employed in its manufacture. He found confirmation for this belief in the fact that pig iron, made with charcoal, a fuel well known to be almost free from sulphur, containing at most a mere trace, was also free from sulphur, or contained it in such small quantity as might safely be considered to have no effect in practice: whereas, pig iron made with the ordinary coke fuel, from precisely similar ore to that used in the other case, contained a notable quantity of this highly injurious element. Taking these facts into consideration, and seeing the high price paid for charcoal iron as compared with coke pig iron, he would strongly recommend to the members of the Institute greater attention to the purity of the fuel they employed in blast furnace operations, and could speak with satisfaction of the efforts made by Mr. Cox to desulphurize and generally to purify coke, and of the undoubted success of that gentleman's experiments. He had thought, however, that more could yet be accomplished in the desulphurizing of coke, and had therefore made experiments on this subject to determine whether or not steam—as such—could be employed as a purifying agent, and he was happy to inform the members that those experiments had been successful. He had secured a patent for this invention, and was making, by consent of the Pontypool Iron Company, continued trials of it, which had confirmed in practice what theory had suggested. The coke oven he employed had a false bottom of perforated

bricks, on to which the coal to be coked was charged as usual. When the dull heavy flame in the oven had nearly disappeared, that is to say, when the expulsion of the bituminous matter was completed, steam was passed under the false bottom and through the same into the oven, necessarily passing into and through the coke. The steam in the oven was kept, as much as possible, under pressure, by checking its escape, so that the hot coke might be permeated completely by the steam, which, acting on the sulphides present in the coke, produced mutual decomposition—the sulphur passing off as a gaseous compound. The length of time required for steaming varied with the quantity of sulphur in the coke. He thought that more extensive trials would confirm the results already arrived at; and he should be glad, at any time, to give information on the subject to any of the members of this Institute.

Mr. Cox said that the intent of his paper had been misunderstood if it was believed that he wished to make out that the composition of the ores had no influence on the quality of the iron produced from them, and thus to ignore the benefits which the labours of the chemist conferred on its manufacture. The discussion would, therefore, necessitate only one or two remarks. Ores he was aware contained many impurities, such as arseniates and others, besides silica and sulphur; but as these last were the most injurious, and were those which he held were chiefly imparted by the fuel, he had confined himself to their consideration. He quite agreed with Mr. Riley as to the fusibility of the compounds of silica with the double base of alumina and lime. A mixture of silica and alumina made, as was well known, an almost infusible fire brick, but if mixed with a little lime it fused immediately. A very small quantity of lime was sufficient to effect this, but the ashes of Welsh coal contained a large quantity, and this compensated for the absence of potash, which was the flux of the ashes of wood charcoal. Although, therefore, it was correct to state that iron would contain more silica in proportion to the quantity contained in the fuel, if made with coal or coke which did not produce heat enough to flux its ashes with rapidity; yet made with coke manufactured as he had recommended, which would do so (and which would be assisted in so doing by the presence of the lime), the larger quantity of ash would cease to produce this injurious effect, and, to that extent, to be a matter of importance. His object had been to call attention to the importance of the quality of the fuel used. In doing this he was not claiming the credit of any new invention—it was universally admitted with respect to charcoal: he claimed for coke no higher consideration—his desire was to show that it could be so nearly assimilated to charcoal as to produce similar results, and to obtain for its manufacture that attention which was necessary to render it so. This he held would be a step in the right direction, and tend materially to the improvement of the trade.

A vote of thanks to Mr. Cox was unanimously agreed to, and the following paper was then read:—

A DESCRIPTION OF A BLAST FURNACE, HAVING AN ELLIPTICAL HORIZONTAL SECTION.

By CHARLES C. ALGER, of Newburgh, New York, United States.

In the present improved state of the art of smelting iron, the appliances may be considered as exhibiting practical knowledge, founded on two sciences—chemistry, and engineering. In the modern blast furnace we recognise this union, and in the correct carrying out of plans embracing chemical action, within spaces of certain construction, where the materials are under the influence of agents kept in motion by mechanical means, we increase efficiency, certainty, and economy, as we apply those rules which have become laws in these sciences.

Looking back on the past, a rapid glance at the history of the applications made in this great fundamental art of the iron manufacture, by which iron ores of all kinds are reduced to metal, by fuels differing greatly in composition, and mechanical characters; some points present themselves as of high importance, and in addressing a society, including those who have advanced the art to its present high state, approaching perfection, I feel that any suggestions, emanating from a co-worker in another country, will be received with indulgence, and criticised with that ability and fairness which every truth seeker must desire. The points to which I would call your attention this time, are form, and capacity of the furnace, as a recipient for the air, ore, fuel, and flux. Information derived from various sources, all tend to prove that the forms of furnaces

have been modified to suit them to the reduction of particular classes of ores with advantage, while the horizontal section of the circular form has been preserved.

The curvature, or in other cases, the angles of the boshes and sides, have been raised to meet and overcome some difficulty in working. While one iron master would adhere to a slight degree of curvature above the boshes, with a given height of furnace, another insists on a regular curve of contraction to the sides, extending to the top, and a greater height in the construction; and generally where the fuel expands, we see that the more nearly vertical line is preserved.

Omitting those cases where this expansion of the fuel occurs, and keeping before us the great points of quantity of materials in the furnace undergoing chemical changes, and pressure and quantity of blast, these apparently different modes of practice, seem to fall within a single rule. In a practice of more than twenty years, the earlier part of which was with charcoal as a fuel, my attention was often called to this influence of form, and in common with other iron masters, much importance was attached to it, as influencing the successful action of the furnace. I went so far as to adopt from nature a form for the diffusion of blast, which would allow a high degree of equality, and my success seemed to be directly, to a great extent, dependent on form of interior of furnace. My natural model was the contour of the flame of a wax candle burning quietly, and I considered that a gaseous fluid, even under pressure, would best consume fuel in a cavity of this form: especially as I often found, that furnaces becoming unserviceable were melted out so as to present a general resemblance to my natural model. Nor would I, at this time, dismiss wholly this influence of interior form, for, in after experience, with that most dense and valuable fuel—anthracite, the effect of any large departure from well known forms, is felt in the duration as well as general working of the furnace.

This general proposition, on careful investigation, became a starting point for improvement with myself and others, for it led me directly to the examination of the influences of a steady blast

of atmospheric air, carrying in its volume sufficient oxygen to burn perfectly a given weight of carbon in a given time. But little progress had been made in this direction before the conclusion was reached, that my success in trials of forms had been more effected by the volume of air thrown into the furnace, than by the particular forms chosen. An appeal to chemical science having been made in relation to this volume, which is more simply stated in weight, the error arising from an insufficient supply of air, became a fact of that glaring character, that it has ever after served as a beacon to warn me from neglecting the application of any science.

When the mechanical means, permit the addition of a sufficient weight of air to consume the fuel, the small variations in the form of the furnace, cease to exert much influence on its working while the burden of fuel and ore remains the same. If the comparison is made between a high and low furnace, then this matter of burthen becomes one of great importance, and it will often appear that the desire for making a furnace with inclined sides higher, arises from the necessity of increasing the burthen of ore and fuel in order that the reduction of the ore may take place before it enters the smelting zone of the furnace. It is probably within the observation of every iron master present that the quantity of materials reposing above the melting zone, and being there prepared for descending slowly, exercises great influence on the regularity of the smelting operations. In close connection with the subject of quantity is the pressure under which the air is introduced, and we have a convenient term of expression as "pillar of blast," which also conveys the idea of equality of pressure. This "pillar of blast" is regulated to the mechanical state of the fuel, coke requiring more pressure than charcoal, and anthracite still greater pressure.

The equilibrium being established between the quantity and pressure of the blast in acting on a chosen weight of fuel, the proportion of ore to the fuel, will become a matter of experience alone; as it is dependent on kind, and quality, of a natural product.

Having briefly alluded to the fact of increased quantity of ore, and fuel, in the upper part of the furnace, proving advantageous in

increasing the regularity, and quantity, of iron in a given time; I wish to more particularly state, what is presumed to be the experience of every iron master consuming coke in this country, as it is with charcoal and anthracite in the United States; that the larger the masses of fuel and ore exposed to mutual action, the less the consumption of fuel and time for a given product of iron, as exemplified in the employment of large furnaces instead of those of moderate dimensions. I have been led to some experimental demonstrations, both in my own furnaces and those of others, which show that we may usefully increase this mass of matter, far beyond the usual measure, and that we actually thus obtain a power of production of metal, which could not have been predicted, from the known results of working smaller furnaces.*

A knowledge of this important principle has led to the erection of furnaces of such large dimensions, that a pressure of five and one-half pounds to the square inch has been overcome by the blast, and yet under judicious disposition of the charge, the central part of the mass at the tuyers was not equally acted on by the air. Indeed, with dense ores and anthracite, furnaces, having a diameter at the crucible of six feet, require that the pillar of blast should be more than five and one-half pounds as the least pressure. Thus, for the dense materials we have a limit of from six to seven feet, as the utmost breadth which such a pillar of blast will penetrate. With coke as fuel, such a pillar of blast would doubtless be found too high for economy of consumption of the fuel, and although a greater diameter could be usefully given, when volume and pillar of blast are duly proportioned, a risk of unequal diffusion of the air would be increased.

These facts having been in mind for several years, I have been led to propose a modification of the usual form of the interior of the furnace, by which its horizontal section approaches the elliptical outline in all its parts.

* "When, however, small melting furnaces are enlarged to twice or thrice their former size, the effects become more strikingly apparent; an economy of fuel to the extent of 150 or 200 per cent., being the practical result."—Mr. Parry, page 34, 1st No. Proc. S. W. Inst. Eng.

In the accompanying drawings, A represents the hearth or crucible, which is of an elliptical or oblong form, in the plane of its horizontal section, but in all other respects formed in the usual manner. B B B B B B are two series of tuyère arches or openings, one on each side, and arranged between the main working arches H H. To these tuyère arches are fitted tuyères and blast pipes in the usual manner, in order to introduce the blasts in the direction of the breadth of the hearth. C C are the dam stones; D D the boshes; and E the stack, bearing the same proportions to the hearth, so far as breadth is concerned, that they do in furnaces of the usual form. F F are arches, one at each end, for the working mouths G G. H H are main arches leading to the lower or tuyère arches.

This form is really that section which the separation of the two halves of a given furnace would make, if they were carried one, two, or more diameters apart, the curves being partially preserved.

The approach to this form has been step by step, each point having been proved as progress was made, until the verification of the principle has left no doubt remaining on my mind in regard to the results which furnaces of this form will insure.

The diagram shows that the crucible has the same interior form as the furnace, and that two tap holes, one at each opposite point of the larger diameter are used alternately. The tuyères are ranged along the sides, so as to blow across the shorter diameter of ellipse, and these may be, in some cases, placed in two rows. One section exhibits proportions and curvatures, such as I have found, best adapted to anthracite fuel and heavy ores, the height being adjusted for this kind of fuel.

In the use of coke fuel I should not depart widely from the proportion of width crossways, and height, which have been found best adapted to making good iron, in a particular district; as my sole intention is to present an improvement rather than innovation: and, in considering this as an important form of furnace, the fact is every moment present to my mind, that we, as iron masters, have improved our art; just in proportion as we have enlarged our fur-

naces; or by enlarging their forms, have increased the burden they can carry, with sufficient pillar of blast. The elliptical form allows us to increase the burden so as to take advantage, both chemically, and mechanically, of that increase of heat, which, in a compound ratio, every iron master knows is produced, where large masses of fuel and ore react on each other. This increased amount of heat, developed by the fuel, so far as my observation has extended, seems to increase the activity of the furnace in two ways. 1st, The melting zone is vertically extended, and the temperature of the reducing zone thereby increased, without the increase of heat in the escaping gases. 2nd, At this higher temperature the oxides of iron part with their oxygen to the carbon much more rapidly and easily than takes place at a somewhat lower temperature in the reducing zone.

In all my furnaces economy in fuel has been considered an important point, as well as the advantage arising from the choice of any location near fuel or ore. The apparatus is, therefore, rendered self dependent: the waste gases being taken off and burned in mixture with air, for generating the necessary heat for producing power and for heating the blast. My plans have always been carried out by placing the boilers and stoves as high as the tunnel heads of the furnaces, leaving the latter open with a chimney top supported on pillars, while the gases drawn out about seven feet below the top, move off by the aid of a higher chimney, at the ends of the boilers and stoves, thus creating draft.

This arrangement aids the blast, and, as the quantity of gas, even with anthracite, much exceeds the amount required to work a hot blast furnace, the excess keeps the materials hot at the top, and consumes as usual in open furnaces. As all experience shows, there are certain irregularities in the working of furnaces which call for much attention from iron masters, such as "bridging" and "slipping," and if we trace these to their causes, we find that certain lodgements of fine coal and dust of ores, become accumulations, which, disturbing diffusion, lead to obstructions of a serious kind. The prevention of these "faults" can be best effected by choice of form, and it is here that we observe the advantage which the ellip-

tical form has over the circular; the nearly vertical sides of the ellipse preventing adhesions, while the longer diameter effectually removes all danger of bridging. Again, this form allows of a regularity of descent of the materials at the part where furnaces are usually contracted, and as there are two points from which the products formed are alternately tapped off, no "backs" can exist at any time.

It is perhaps purely theoretical, but in observing the distribution of heat in this form of furnace, it has appeared to me that two foci of heat exist below, corresponding to the cross diameters of the shorter curves. The vexation arising from "chilling" is removed by the intensity of the heat near the top of the crucible being maintained, by the rapid descent of the melted products, as they form and are deposited or removed.

It is hardly worth the time necessary to dwell on these, and other well known embarrassments, which attend the ordinary form of furnace, as it must be apparent to all; that in the greater volume and weight of acting materials, the higher intensity of heat and judicious form of apparatus, the control which the manager has obtained, is such, that, through a wide range, he may adjust his means so as to produce every variety of iron, from the lowest "gray" to the highest "white" kinds. Nor does the management of larger volume and weight become a departure from known practice, as applied in other cases; for it is strictly analagous to having at hand copious or reserved power in the steam engine, or purely mechanical means, to effect a certain result on which much of success depends. In adjusting the volume of blast, my calculations are made by substituting weight of air for volume. Thus, a furnace supposed to consume fifty tons of coke, or anthracite daily, the pure carbon being 88 per cent. of the weight of the fuel, must receive in that time, at least, three hundred tons of air, or so much as will burn every particle of the carbon into carbonic oxide.

Theoretically this quantity seems large, when we consider how great a part of the carbon is burned by the oxygen of the oxide of iron, and also the oxygen in the carbonic acid disengaged from the

limestone; but my practice with accurately closed apparatus has shown that if we would work rapidly, and retain a high vertical zone of melting and reducing actions in the furnace, we must not expect to abstract all the oxygen from the air we throw in. It is not all consumed in the closest workings, until it burns in a purely gaseous medium under the boilers. The pillar of blast is a consideration of a more mechanical character—it must be high enough to cross fairly the narrower diameter of the ellipse; allowing thus for the practical removal of the oxygen from half the stream, and it should be subject to the least possible momentary variation of pressure, while the average pressure may be easily varied.

Whatever kind of fuel is used, (the remark applies especially to charcoal and coke,) that "sharpness" of action which causes a rapid dispersion of heat obtained should be avoided, for *complete chemical action necessarily involves time as an element.*

These facts and remarks which I have the honour of submitting to this society, I trust will induce others, who are favourably situated, to inquire into the conditions necessary to the rapid production of crude iron from the ore, with the least consumption of fuel; and that they will coincide in opinion with me, that, although the production is brought nearer the theoretical requirements than we have credit for, there still remains a field for improvement.

DISCUSSION.

Mr. PARRY said that as far as his experience went, he could not see any advantage to be gained by adopting the proposed form of furnace. With a pillar of blast of 4lbs. they could, if desired, increase the make of a furnace to 200 tons per week, but they could not increase the diameter of the hearth without proportionately increasing the pillar also. The usual pressure of blast was 3 to 3½lbs. per inch, which would penetrate to the centre of the furnace. Hearths in general were about seven feet in diameter, and he found it to be a rule for ascertaining the requisite pillar of blast to take half-a-pound for every foot diameter of the hearth. Supposing the blast penetrated the centre of a hearth 7 feet in diameter, that would be the same as an ellipse of 5 feet by 10. An ellipse of 5 feet by 10 would expose a far greater amount of cooling surface than a circle of the same area would, and he should anticipate a corresponding increased consumption of fuel per ton of make. As there was a greater radiating surface, it must follow that there could be no economy of fuel, but the reverse. With a

fuel like anthracite, requiring a very high pressure of blast to insure active combustion in the central parts of the furnace, the plan might be found advantageous where it was deemed desirable to have an increased make per furnace; but with other fuels he thought the capacity of furnaces might be yet increased to profit, with easily attainable pressures, still retaining the circular section. It might do to have only one long furnace like a mine kiln, making 1000 tons per week, but if a tuyere had to be changed the whole of the works must stop while it was being done. His opinion was, that the use of this furnace would lead to a somewhat increased consumption of fuel, as the cooling surface was greater in proportion to area than in one of circular section.

Mr. Roberts had found it possible, with a pillar of blast of $2\frac{3}{4}$ lbs., to make 190 tons per week, by substituting one third coke for a corresponding quantity of coal; this coke was made from their ordinary coal, and the iron produced was average forge iron. The diameter of the hearth in this case was seven feet.

Mr. James had had the pleasure of meeting Mr. Alger, and of discussing with him the merits of his Blast Furnace. He believed a furnace of the description might be worked successfully, but did not see a prospect of it accomplishing anything that could not be done with a large furnace of the circular form.

Mr. Roper said that there was one point connected with the Elliptical Furnace which had not been commented on—one which might be considered an advantage,—he alluded to the relation of the area of the proposed furnace to the "pillar of blast," as compared with that exhibited in a circular furnace. The dimensions of Mr. Alger's furnace were, he believed, 27 feet for the major axis, and 5 feet for the minor axis of the ellipse,—taking a horizontal section at the level of the tuyeres,—which would give an area equal to that of a circular furnace, of about 11 feet 6 inches diameter. The pressure of blast proposed for the elliptical furnace, was 5 lbs. to the inch; which was probably more than sufficient for a furnace of ordinary height, using coke; while he considered that this pressure would be barely enough for a furnace of 11 feet 6 inches diameter. So far there appeared to be an advantage in the use of elliptical furnaces; but he must remind them of a difficulty in working such furnaces, viz.: the necessity for using very long bars to "work the forepart;" and in case of any obstruction, such as a scaffold over the middle tuyeres, or any chilling on the bottom, this would be peculiarly objectionable. On the whole however, if it were satisfactorily proved that furnaces, capable of producing more than 250 or 300 tons were desirable, it appeared that the plan adopted by Mr. Alger was the only one to follow; but, he considered that quality was of more importance than quantity, and regretted that greater attention was not paid to this matter by British Ironmasters.

The PRESIDENT said he did not see that any great advantage could arise from the adoption of Mr. Alger's form of furnace. We could now obtain, from properly constructed furnaces of circular section, a sufficiently large make to reduce the cost of labour to a minimum, and he did not think the alteration in shape would improve the yield of coal.

The proceedings then terminated.

ALGER'S PATENT FURNACE.

Fig. 1. *Side Elevation.*

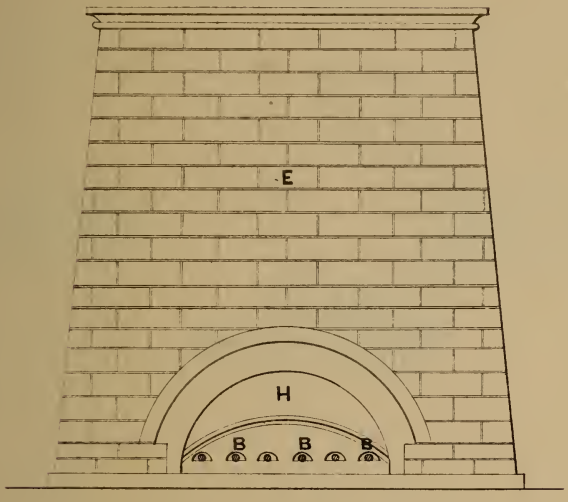
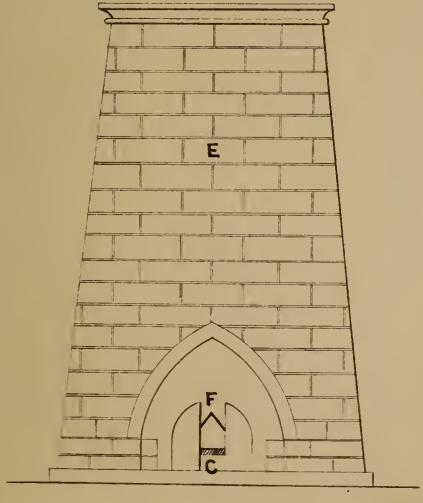


Fig. 2. *End Elevation.*



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ALCER'S PATENT FURNACE.

Fig. 3. *Plan.*

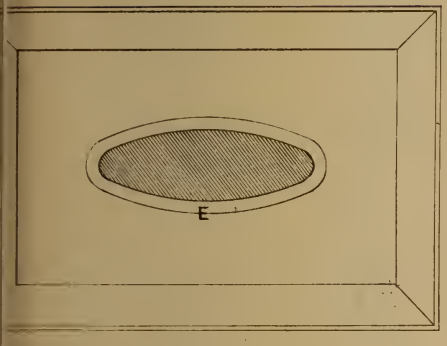

Fig. 4. *Horizontal Section.*

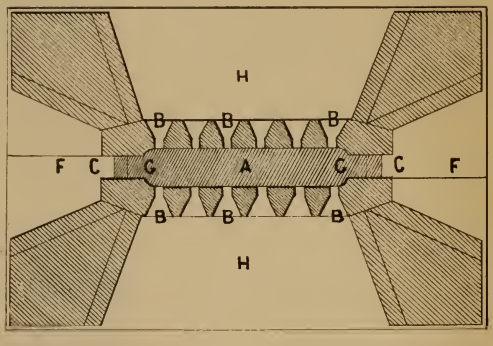

Fig. 5. *Longitudinal Section.*

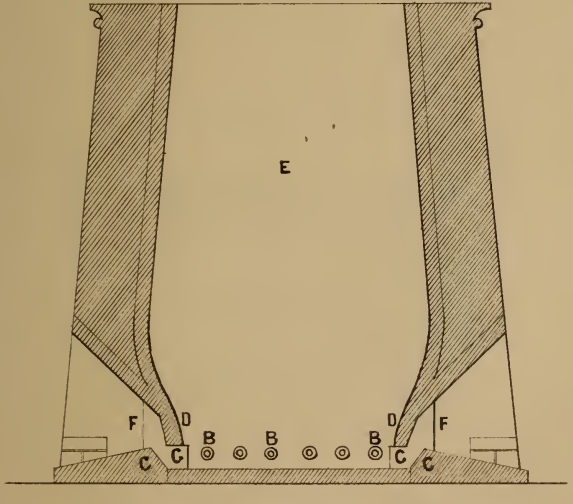

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Fig. 6. *Transverse Section.*

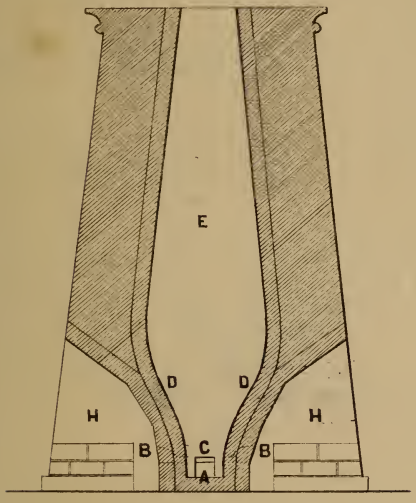
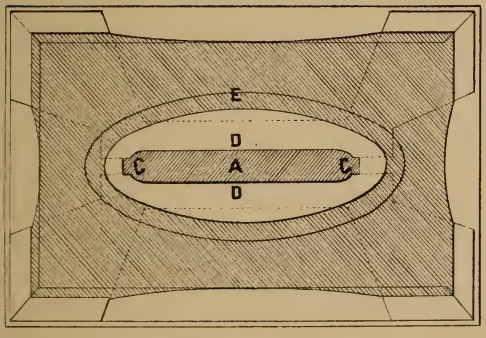


Fig. 7. *Horizontal Section.*



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PROCEEDINGS.

20th October, 1858.

The General Meeting of the Members was held at the Town Hall, Cardiff, on Wednesday, the 20th October, 1858;

The President in the Chair.

The Secretary read the minutes of the last meeting which were confirmed.

Mr. Cox proposed that Rule 18 be cancelled and the following substituted:—

"That the Council be empowered to hold Meetings of the Institute at whatever times and places they may from time to time think fit; but that not less than four shall he held in each year."

Mr. Huxham seconded the proposition, which was carried unanimously.

Mr. R. H. Rhys proposed that the following be substituted for Rule 35:—

"The President, Treasurer, and Secretary, shall be elected annually, at the Annual Meeting held in the month of July in

each year; and one-third of the Vice-Presidents and Council shall go out of office annually, but be eligible for re-election. The order in which such members shall go out of office, for the first two years, shall be regulated by the Council at their April meeting; but in no case, shall any member continuously remain in office for more than three years without re-election. At the April meeting, in each year, the names of the retiring office-bearers shall be declared by the President, and, at the same meeting, the members to succeed them shall be nominated; whereupon the Secretary shall cause printed lists of the proposed candidates to be prepared, and send a copy to each member of the Institute, who must return the same, sealed, to the Secretary, on or before the day of the Annual Meeting, with the letters V.P. affixed to the names of the candidates whom he is desirous of electing as Vice-Presidents, and the letter C affixed to the names of the candidates he is desirous of electing to be Members of the Council."

The proposition was seconded by Mr. MENELAUS, and carried unanimously.

The following paper was then read:—

ON THE SOUTHERN PORTION OF THE SOMERSETSHIRE COAL FIELD.

By MR. G. C. GREENWELL, F.G.S.

In the following paper it is my intention to describe that portion of the East Somersetshire Coal Field which is comprised between what is probably the lowest part of the Basin, in the neighbourhood of Radstock, and its outcrop where lying against the Mountain Limestone of the Mendip Hills.

This coal field is interesting as being much overlaid by the more recent formations of New Red Sandstone, Lias, and Oolite: as having previous to this overlay been subjected to numerous contortions and dislocations; as being probably the thickest development of coal measures in the kingdom, and as the most southerly true coal district yet discoved in the Island.

The upper Coal Measures are passsed through in the Tyning Pit, at Radstock, of which the following is an account of the strata:

	Strata.	*Fas. Ft. Ins.*	*Fas. Ft. Ins.*
	Lias.		
1	Out set and Yellow Marl	2 5 0	
2	Black Marl	1 1 10	
3	Light blue marly Clay	1 4 2	
	New Red Sandstone.		5 5 0
4	Red Marl	7 1 0	
5	White Marl Stone	0 2 0	
6	Red Marl	1 0 0	
7	White Marl Stone	0 2 4	
8	Red Marl	0 5 0	
	Carried forward	4 4 9	5 5 0

	Strata.	Fas.	Ft.	Ins.	Fas.	Ft.	Ins.
	New Red Sandstone.						
	Brought forward	9	4	4	5	5	0
9	White Marl Stone	0	1	8			
10	Red Marl	2	5	0			
11	White Marl Stone	0	5	3			
12	Red Marl, with Water, 700 gallons per minute	12	3	5			
13	Hard reddish grey Sandstone	0	1	4			
14	Red Marl	1	2	0			
	Magnesian Conglomerate.				27	5	0
15	Hard Red Conglomerate	3	1	0			
	Lower New Red Sandstone.				3	1	0
16	Red Metal, with red post Girdles	5	1	8			
17	Blue Metal	3	3	11			
18	Red and blue Metal	2	1	0			
	Coal Measures.				11	0	7
19	Fire Clay	0	2	2			
20	Blue Metal	0	5	8			
21	Grey Metal Stone	3	3	3			
22	Grey Post	2	4	4			
23	Blue Metal	2	1	11			
24	Grey Metal Stone	0	2	2			
25	Blue Metal	0	1	2			
26	Grey Metal Stone	1	1	2			
27	Black Metal	0	2	7			
28	Fire Clay	0	3	0			
29	Blue Metal	1	2	7			
30	Gray Post	0	5	6			
31	Blue Metal	0	1	6			
32	Grey Metal Stone	3	0	0			
33	Blue Metal	3	4	0			
34	Grey Metal Stone	1	5	8			
35	Black Metal	0	0	6			
36	Blue Metal	0	2	7			
37	Fire Clay	0	2	6			
38	Grey Metal Stone	1	4	3			
39	Gray Post, called "Dice Greys," with soft Partings	0	3	6			
40	Grey Metal Stone	7	0	9			
	Carried forward	34	0	9	47	5	7

	Strata.	*Fas.*	*Ft.*	*Ins.*	*Fas.*	*Ft.*	*Ins.*
	Coal Measures.						
	Brought forward	34	0	9	47	5	7
41	Grey Post.....	0	5	1			
42	Black Metal.....	0	0	2			
43	Grey Post.....	0	5	9			
44	Blue Metal	2	2	0			
45	Great Vein Coal (above the Overlap Fault)	0	2	0			
					38	3	9
46	Soft Thill.....	0	3	3			
47	Fire Clay	0	2	2			
48	Black Metal.....	0	0	7			
49	Grey Metal Stone	5	3	0			
50	Top Little Vein Coal (above the Overlap Fault)	0	1	4½			
					6	4	4½
51	Black Metal.....	0	2	0			
52	Tom Coal.....	0	0	4½			
					0	2	4½
53	Grey Metal Stone	2	4	0			
54	Dark grey Post	1	0	0			
55	Grey Post, with Coal Partings	2	0	0			
56	Grey Post.....	0	4	0			
57	Blue Metal	1	2	0			
58	Black Metal, with Ironstone Girdles	0	1	8			
59	Grey Post.....	0	3	4			
60	Blue Metal	0	3	0			
61	Middle Vein Coal (below the Overlap Fault).....	0	1	10½			
					9	1	10½
62	Fire Clay	3	3	5½			
63	Black Metal.....	2	0	2			
64	Grey Metal Stone	5	2	6			
65	Grey Post.....	2	4	0			
66	Top Little Vein Coal (below the Overlap Fault).....	0	1	2			
					13	5	3½
67	Fire Clay	1	0	6			
68	Grey Post.....	5	5	3			
69	Dark grey Post	0	0	6			
70	Grey Post.....	0	0	9			
	Carried forward	7	1	0	116	5	3

	Strata.	*Fas.*	*Ft.*	*Ins.*	*Fas.*	*Ft.*	*Ins.*
	Coal Measures.						
	Brought forward	7	1	0	116	5	3
71	Dark grey Post	0	0	3			
72	Grey Post.....	0	1	3			
73	Dark grey Post	0	1	3			
74	Grey Post..	0	1	7			
75	Soft black Metal.....	0	0	6			
76	Blue Metal	1	2	9			
77	Middle Vein Coal (below Overlap Fault)	0	2	0			
					9	4	7
78	Fire Clay	0	3	0			
79	Grey Post.....	2	0	9			
80	Blue Metal	1	1	10			
81	Fire Clay	0	1	2			
82	Blue Metal	0	1	1			
83	Grey Metal Stone	4	2	0			
84	Fire Clay	0	2	3			
85	Grey Post.....	2	0	6			
86	Blue Metal	0	1	0			
87	Grey Post.....	1	3	8			
88	Grey Metal Stone	0	1	6			
89	Grey Post.....	3	1	6			
90	Blue Metal	1	0	0			
91	Slyving Vein Coal: ft. ins.						
	Shale..... 0 2						
	Coal 0 10						
	Coaly Shale 1 7½						
	Fire Clay 2 10½						
	Blue Metal 24 10						
	Coal 1 5						
		5	1	9			
					22	4	0
92	Shale.....	0	0	1½			
93	Black Metal.....	0	1	6			
94	Fire Clay	1	0	7			
95	Grey Post.....	1	0	0			
96	Blue Metal	1	0	0			
97	Grey Post.....	0	1	0			
98	Blue Metal	0	3	4			
99	Grey Post.....	1	0	8			
	Carried forward	5	1	2½	149	1	10

	Strata.	Fas.	Ft.	Ins.	Fas.	Ft.	Ins.
	Coal Measures.						
	Brought forward	5	1	2½	149	1	10
100	Blue Metal	1	2	6			
101	Bottom Little Vein:						
	Shale..... ..... 0 2						
	Coal 1 2						
		0	1	4			
					6	5	0½
102	Thill	0	1	6			
103	Grey Post.....	0	4	8			
104	Blue Metal	0	4	0			
105	Grey Post.....	1	3	3			
106	Blue Metal	2	0	9			
107	Bull Vein Coal.....	0	2	4			
					5	4	6
108	Thill	0	0	6			
109	Fire Clay	0	3	0			
					0	3	6
	Total Depth.....	Fathoms			162	2	10½

The depth of Strata intervening between the lowest Stratum of the last section and the uppermost Coal Measure Stratum of the following section of the Norton Hill Colliery, is approximately correct, being taken from the sinking of the Old Grove Colliery, at Timsbury, which is about three miles North North West of Norton Hill.

The Strata passed through in sinking Norton Hill Colliery are as follows:

	Lias.						
1	White Lias	2	1	6			
2	Soft Yellow Lias	3	0	0			
3	Blue Marl	1	0	0			
4	Black Marl	0	5	0			
5	Blue Lias.....	0	5	0			
					7	5	6
	New Red Sandstone.						
6	Red Sandstone.....	19	4	6			
					19	4	6
	Carried forward	Fathoms			27	4	0

	Strata.	Fms.	Ft.	Ins.	Fms.	Ft.	Ins.
	Brought forward				27	4	0
	Magneisian Conglomerate.						
7	Red Conglomerate	9	2	0	9	2	0
	Lower New Red Sandstone.						
8	Red Metal	2	1	6	2	1	6
9	Black Metal	4	0	0			
10	Blue Metal	1	0	0			
11	Black Metal	0	4	6			
12	Grey Metal Stone	9	0	0			
13	Black Metal	2	0	0			
14	Grey Metal	1	3	0			
15	Grey Post	2	0	0			
16	Red Metal	9	0	0			
17	Grey Post	2	3	0			
18	Blue Metal	1	3	0			
19	Red Metal	22	1	6			
20	Grey Post	2	4	6			
21	Blue Metal	0	4	6			
22	Red Metal	17	0	0			
23	Soft blue Metal	0	4	6			
24	Grey Metal Stone	5	1	6			
25	Grey Post	4	0	0			
26	Soft Thill Stone	3	0	0			
27	Black Metal with a little Water	4	3	0			
28	Blue Metal	4	3	0			
29	Coal	0	0	$2\frac{1}{2}$	98	0	$2\frac{1}{2}$
30	Black Thill	1	0	0			
31	Coal	0	0	2	1	0	2
32	Soft Thill	1	3	0			
33	Fire Clay	1	3	0			
34	Blue Metal	2	1	6			
35	Coal	0	0	2	5	1	8
36	Black Metal	0	3	0			
37	Coal	0	0	1	0	3	1
	Carried forward	Fathoms			144	0	7

	Strata.	*Fas.*	*Ft.*	*Ins.*	*Fas.*	*Ft.*	*Ins.*
	Coal Measures.						
	Brought forward				144	0	7½
38	Black Metal.....	0	2	0			
39	Fire Clay.....	3	0	0			
40	Blue Metal	4	3	0			
41	Coal	0	0	2			
					7	5	2
42	Fire Clay.....	1	3	0			
43	Blue Metal	2	1	6			
44	Coal	0	0	3			
					3	4	9
45	Black Metal.....	0	0	6			
46	Coal	0	0	1			
					0	0	7
47	Fire Clay.....	1	3	0			
48	Grey Post	0	4	0			
49	Blue Metal	1	3	6			
50	Coal	0	0	1			
					3	4	7
51	Fire Clay.....	0	3	0			
52	Coal	0	1	0			
					0	4	0
53	Fire Clay.....	1	0	0			
54	Grey Post.....	0	3	0			
55	Blue Metal	0	4	0			
56	Faulty Strata	3	1	0			
57	Great Vein Coal	0	1	8			
					5	3	8
58	Fire Clay.....	2	3	0			
59	Grey Post	4	3	0			
60	Blue Metal	0	4	6			
61	Little Vein Coal	0	1	2			
					7	5	8
62	Fire Clay.....	2	0	0			
63	Coal	0	0	3			
					2	0	3
64	Fire Clay.....	1	0	0			
65	Coal	0	0	3			
					1	0	3
66	Fire Clay.....	1	0	0			
67	Blue Metal	2	3	0			
	Carried forward	3	3	0	174	5	6½

	Strata.	Fas.	Ft.	Ins.	Fas.	Ft.	Ins.
	Coal Measures.						
	Brought forward	3	3	0	174	5	6½
68	Grey Post	2	0	0			
69	Blue Metal	1	3	0			
70	Coal	0	0	6			
					7	0	6
71	Fire Clay	0	1	0			
72	Coal	0	0	3			
					0	1	3
73	Fire Clay	1	3	0			
74	Grey Post with Coal Pipes	3	4	6			
75	Blue Metal	1	0	9			
76	Third Vein of Coal	0	2	4			
					6	4	7
77	Coal Strata not recorded	19	0	2			
78	Coal	0	1	6			
					19	1	8
79	Coal Strata not recorded	6	2	0			
80	Coal	0	1	0			
					6	3	0
	Total Depth	Fathoms			214	4	6½

Explanation of Terms used.

Grey Metal—Silicious Grey Shale.
Blue Metal—Blue Argillacious Shale.
Grey Post—Grey Gritty Sandstone.
Thill—Underclay.
Black Metal—Black Bituminous Shale.
Red Metal—Red Shale.

The last 6½ fathoms are proved by a staple sunk about 75 yards to the rise or West of the Pit.

The portion of the Coal Field proved by these sections is shewn upon the "Section of Strata from Braysdown Colliery to the Road from Old Down to Shepton Mallet," which is a section constructed from actual survey, and from Braysdown Colliery as far as the Outcrop of the Lowest Stratum, proved at Norton Hill Colliery, it may be taken as substantially correct.

Between this and the first Coal Stratum pierced by the New Rock Colliery, there is a tract of unexplored Strata, undoubtedly all Coal measures and so coloured. At the New Rock Colliery and neighbourhood the seams of Coal proved are as follows:—

No.	Name of Seam.	*Section.*			*Depth from Surface at New Rock.*
					Fas
1	New Rock or Globe Vein	Coal	0	9	91
		Shale	3	0	
		Coal	1	10	
			5	7	
2	Small Coal Vein	Coal	3	0	144
3	Two Coal Vein	Coal	1	3	158
		Shale	2	6	
		Coal	0	9	
			4	6	
4	Warky Course.....	Coal	0	11	170
		Shale	4	9	
		Coal	1	3	
			6	11	
5	Garden Course.....	Coal	0	9	200
		Shale	0	6	
		Coal	2	6	
			3	9	
6	Strap Coal	Coal	0	9	240
7	Great Course	Coal	0	9	260
		Shale	0	6	
		House Coal	2	0	
		Shale	1	0	
		Smith Coal	2	3	
			6	6	

No.	Name of Seam.	Section.			Depth from Surface at New Rock.
					Fas.
8	Dungy Drift.....	Coal	3	0	295
9	Perkins Course	Coal	0	9	307
		Shale	1	6	
		Coal	0	9	
		Shale	1	6	
		Coal	0	9	
			5	3	
10	Hard Coal	Coal	1	6	313
		Shale	1	6	
		Coal	1	6	
			4	6	
11	Foot Coal.....	Coal.....	1	0	318
12	Shoots Vein.....	...	...		327

Beyond this point, and until we come to the outcrop of the Limestone, there are no actual explorings; but from the dip of the strata at the New Rock and that of the Mountain Limestone, it is probable that those seams of Coal which elsewhere, as at the Old Morewood Colliery, are found under the New Rock Seams, will be found to exist in a tolerably regular and undisturbed state.

At some point in this tract the Millstone Grit will crop up under the Red Conglomerate, in and beyond which, no Coal will, of course, be found.

By admeasurement of the section vertically, we find that the entire thickness of Coal Measures, in the centre of the Basin, is not less than 9,000 feet, a depth at which, if the temperature of the Earth increases at the ordinary supposed rate, it will have reached the boiling point of water.

I am, however, by no means inclined to fall in with the general opinion on this point, and believe that on further observations it will be found that, as we descend deeper, the rate of increase will diminish materially.

The quality of the Coal of this coal field is very variable: that of the upper measures is generally firm, working very large and making a very cheerful and durable fire—it contains a considerable amount of gas, yielding according to different reports from 8,600 cubic feet to 10,000 cubic feet of gas per ton of Coal. It is, however, somewhat sulphury, and leaves, after burning, more ash than the better description of Coal found in the North of England.

As we descend the Coal becomes, generally speaking, less free burning, and is not so hard as that lying above. It is also a little more free from sulphur.

Still lower down the firmness diminishes, and the lowest seams are very friable, but fine and pure in quality, furnishing Coal which, for coking, smiths, and iron manufacturing purposes, cannot be excelled.

There is a very remarkable peculiarity in this Coal field, consisting of a thick stratum of Red Metal which lies between the first and second series of seams.

This has been proved in a stone drift driven from the bottom of the Middle Pit, at Radstock, to cut the seams of Coal lying on the dip side of the 100 fathom fault shewn on the section.

It is also proved in the Norton Hill and Timsbury Old Grove sinkings.

After much search I have been unable to find any organic remains in this stratum, and I am inclined to believe that its impregnation with iron has been unfavourable to the growth of plants.

The character of this stratum is very similar to that of number 16 of the section of strata sunk through in the Tyning Pit, and which, with numbers 17 and 18, may be said to correspond with the Lower New Red Sandstone of other districts; number 15,

called also the Magnesian Conglomerate, representing the Magnesian Limestone.

There is also beneath the Norton Hill seams, and above those worked at New Rock, a thick stratum of hard bluish sandstone or post, called "Pennant Rock," which yields good flags, and is extensively used as a building stone: in fact it is, with a few exceptions, the only quarry stone of the Coal field, the erections of stone in the district, being generally built of the excellent material afforded by the Lias, which also contributes lime for the purpose.

These Coal Measures, particularly the upper series, abound in organic remains of plants, some of which are figured in the drawings accompanying this paper.

The Caulopteris Primœva, a tree fern, is, according to Sir Charles Lyell, comparatively rare, and the only specimen figured in Lindley and Hutton's Fossil Flora was obtained in the neighbourhood of Radstock. I have only found one specimen.

The Sigillaria figured, is also, I believe rare, as I am not able to find any drawing of it in Artis, Lindley and Hutton, or any of the works on Geology which I have hitherto met with: and the same remark applies to the Sphenopteris (?)

I have not as yet met with any remains of fish, as occasionally found in the collieries of the North of England, and the absence of concretions of iron pyrites, amorphous or crystallized, so frequently found in the Coal of other Coal fields, is remarkable in this.

As examples of the contortions and dislocations already alluded to, reference may be made to that very peculiar fault, called the Overlap Fault, which traverses a portion of the Radstock Royalty, and is shewn on the section.

As is there seen, many of the Coal beds are repeated; but how this has occurred is very difficult to explain, unless we suppose that the Coal strata thus thrust in as it were, are some that were displaced at the convulsion which produced the 100 fathom fault. This, however, is not likely, as only through a portion of its course does the "Overlap" run in the same direction as this great fault.

A small but similar Overlap fault, of which a section is shewn, occurs also in the Wellsway Colliery, at Radstock, traversing a considerable extent of district. The cause of these Overlaps is well worthy of investigation. One thing appears certain, that, whereas ordinary faults have been produced by simple upheaval or depression of the strata, the Overlap Fault chiefly owes its origin to lateral pressure.

The probable period of this fault was, therefore, that of the thrusting up through the coal field of the Mountain Limestone, and Old Red Sandstone of the Mendip Hills. A remarkable example of the contortion of the strata occurs at the Vobster Colliery, of which a section accompanies this paper. In this it will be observed that the pit passes through the same seam of Coal three times, and the position of the seams at various depths, is shewn by the stone drifts driven to cut the Coal from various parts of the shaft.

This colliery is situated very near the Mountain Limestone near Wells, and in this neighbourhood the strata are intersected by several very large faults. A somewhat similar twist occurs at Nettlebridge. The strata on the West side of the turnpike road dip to the North at an angle of about 37°, but as we proceed East, the inclination becomes steeper until the seams are vertical; and still further to the East they turn over altogether, so that at the Nettlebridge pit the dip of the strata is to the South at an angle of 80°; the underclays of the Coal seams on the West side of the turnpike forming the roof of the Coal at Nettlebridge.

On following the seams of Coal downwards, they will be found to become first vertical, and gradually to acquire their North dip. A vertical shaft, sunk deep enough at this point, would thus pass through the same seam twice, first where its dip would be South, and afterwards North.

A reference to the section of the Coal field, will shew that the bottom of the basin is at Radstock, at which point the strata commence rising to the North East; but in this direction, no explorings have been made, excepting by a borehole near Coombe Hay, where

the Coal Measures were not reached, although there can be little doubt of their existence at this point.

On the North West the Coal field extends a considerable distance, possibly by Hallatrow, Sutton, and Compton Dando, to Keynsham, and being thus in all probability connected with that at Bristol, the Bristol seams corresponding with seams of Coal not yet proved in the Radstock section, but probably lying between the Norton Hill and New Rock seams, but this portion of the subject will require further investigation.

DISCUSSION.

Mr. Bassett thought the meeting would be glad to have information as to the price of cutting and raising the thin veins of coal in the Somersetshire district, and their average thickness. He had understood that very thin veins were considered workable in that district, and that they were cheaply got.

Mr. O'Donnoghue (who represented Mr. Greenwell,) replied that Mr. Greenwell's paper did not treat on the cost of working the coal; that would perhaps afford him matter for another paper. With respect to the thicknesses of the veins, none reached three feet, and the average was under two. The Bull Vein was 2 feet 2 inches, but for a very short distance came up to perhaps 12 or 14 feet, but this was exceptional. The thinnest seam now being worked was 1 foot 2 inches; sometimes a vein 1 foot thick had been worked, but in no instance had anything thinner been attempted.

Mr. Clark enquired what was the general inclination of the measures, and whether bands of argillaceous ironstone were met with. He would likewise like to know whether carburetted hydrogen existed in any quantity.

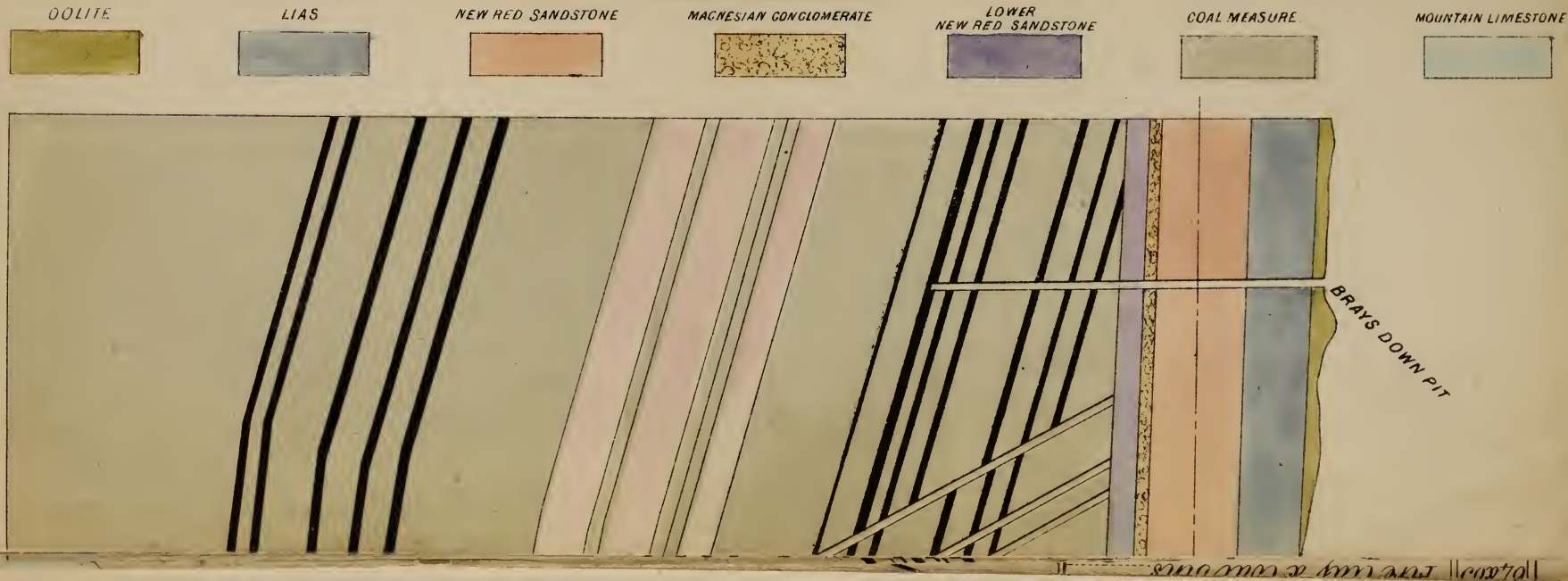
Mr. O'Donnoghue said that the general dip was about 10°, but in some cases it was very variable. Bands of argillaceous ore were met with, but were rarely more than an inch to an inch and a half thick. In the upper measures there was no carburetted hydrogen whatever, but the lower ones contained it in some quantity.

Mr. Dickinson said, that having some knowledge of the subject connected with which, the paper just read opened out so many valuable facts, it would be unfortunate to have any single point not strictly correct. The paper speaking of the strata, said that the aggregate thickness of the Somersetshire coal measures was probably greater than that of any other in the kingdom. He had drawn out some sections, a copy of which hung on the wall opposite, and which shewed 6,000 feet of coal measures of the Lancashire Coal Field, besides which

SOMERSETSHIRE COAL FIELD,

SECTION FROM BRAYS DOWN COLLIERY NEAR BATH TO MARSHALL'S HILL QUARRY NEAR SHEPTON MALLET.

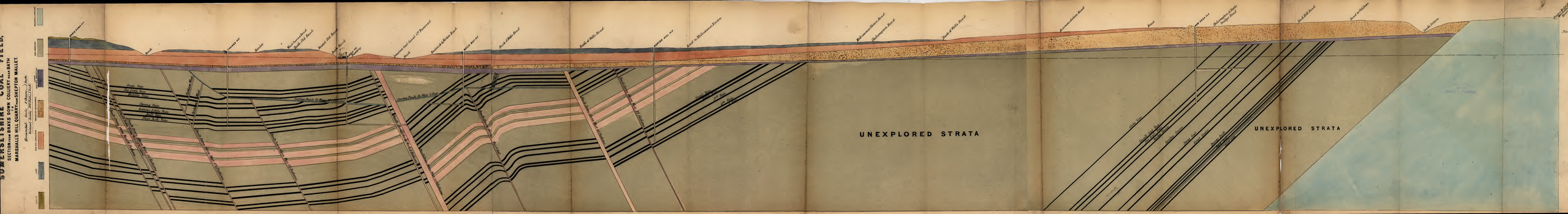
Horizontal Scale, 8 Chains — 1 Inch.
Vertical Scale, 300 Feet — 1 Inch.



SOMERSETSHIRE COAL FIELD.

SECTIONS ACROSS THE COAL MEASURES FROM NORTH TO SOUTH

MARSHALLS HILL COLLIERY to SHEPTON MALLET



64&65	Fire Clay & Coal Stns.						
			0	4	6			
66	Fire Clay.		0	2	2	7	5	8
			2	0	3	2	0	3
			17	0	2			
				1	6	17	1	8
79	Coal Strata not recorded							
80	Coal.							
			6	2	0			
				1	0	6	3	0
						214	4	6½

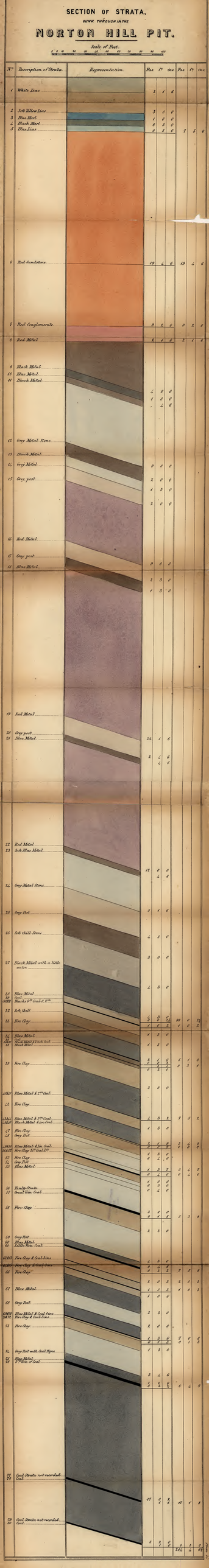
Plate 20.

SECTION OF STRATA,

SUNK THROUGH IN THE

NORTON HILL PIT.

Scale of Feet.

1 8 16 24 32 40 48 56 64 72 80 88 96 104

No.	Description of Strata.	Representation.	Fms.	Ft.	Ins.	Fms.	Ft.	Ins.
1	White Lias			2	6			
2	Soft Yellow Lias			3	0			
3	Blue Marl			1	0			
4	Black Marl			0	5			
5	Blue Lias			6	5		7	5
6	Red Sandstone			18	4		19	4
7	Red Conglomerate			0	2		0	2
8	Red Metal			2	1		2	1
9	Black Metal							
10	Blue Metal							
11	Black Metal			4	0			
				1	0			
				0	4			
12	Grey Metal Stone							
13	Black Metal							
14	Grey Metal			0	0			
15	Grey peat			2	0			
				1	3			
				2	0			
16	Red Metal							
17	Grey peat							
18	Blue Metal			0	0			
				2	3			
				1	3			
19	Red Metal							
20	Grey peat							
21	Blue Metal			22	1			
				2	4			
					4			
22	Red Metal							
23	Soft Blue Metal							
				17	0			
					4			
24	Grey Metal Stone							
25	Grey Peat			3	1			
26	Soft Shell Stone			4	0			
27	Black Metal with a little water			3	0			
				4	3			
28	Blue Metal							
29	Soft Shell							
30	Black 5th Coal & 2nd							
31	Fire Clay		2	3	0	80	0	0
			1	0	2	1	0	2
32	Blue Metal		1	3	0			
33	Blue Metal & 9 inch Coal		1	3	0			
34	Black Metal							
35	Fire Clay		5	1	0	1	1	0
			1	0	0	0	3	1
36	Blue Metal & 2nd Coal		3	0	0			
37	Fire Clay							
38	Blue Metal & 9th Coal		4	3	2	7	5	2
39	Black Metal & 3rd Coal							
40	Fire Clay		1	3	0			
41	Grey Peat							
42	Blue Metal 42m. Coal		2	1	0	3	2	0
43	Fire Clay 2d Coal 18		1	3	0	0	5	0
44	Fire Clay		0	4	0			
45	Grey Peat							
46	Blue Metal		4	3	2	1	4	0
			0	4	0	0	4	0
47	Faulty Strata		1	1	0			
48	Small Fire Coal		0	3	0			
			0	2	0			
49	Fire Clay		2	1	0			
			0	4		5	3	1
50	Grey Peat		2	3	0			
51	Blue Metal							
52	Little Fire Coal							
53	Fire Clay & Coal Stone		4	3	0			
54	Fire Clay & Coal Stone		0	2	0			
55	Fire Clay		0	2	2	7	5	0
56	Fire Clay							
			2	0	3	2	0	3
57	Blue Metal		1	0	3	1	0	3
58	Grey Peat		1	0	0			
59	Blue Metal & Coal Stone		2	3	0			
60	Fire Clay & Coal Stone							
61	Fire Clay		2	0	0			
62	Grey Peat with Coal Pipes		1	3	0			
63	Blue Metal							
64	2nd Run of Coal		3	4	0			
			0	4	0	0	4	0
65	Coal Strata not recorded							
66	Coal							
			17	0	0	17	0	0
				4	0		4	0
67	Coal Strata not recorded							
68	Coal							
			6	3	0	12	2	0
				1	0	2	0	0
						14	4	0

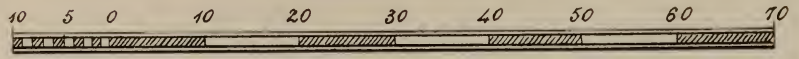
SECTION OF STRATA,

SUNK THROUGH IN THE

TYNING PIT,

RADSTOCK COLLIERY.

Scale of Feet.



N°.	Description of each Stratum	Representation.	Fas.	Ft.	In.	Fas.	Ft.	In.
1	Outset & Yellow Marl		2	5	0			
2	Black Marl		1	1	10			

SECTION OF STRATA,

SUNK THROUGH IN THE

TYNING PIT,

RADSTOCK COLLIERY.

Scale of Feet.

N°	Description of each Stratum	Representation.	Fms.	Ft.	In.	Fms.	Ft.	In.
1	Gravel & Yellow Marl			2	5	0		
2	Black Marl			4	1	10		
3	Light blue marly Clay			1	4	2	8	5	0
4	Red marl			2	1	6			
5	White marl stone			0	4	0			
6	Red marl			1	0	6			
7	White marl stone			0	2	4			
8	Red marl			0	0	6			
9	White marl stone			0	1	6			
10	Red marl			2	5	0			
11	White marl stone			0	5	5			
	(100 Gallons of Water per minute.)								
12	Red marl			12	3	5			
13	Hard reddish grey sandstone			0	1	4			
14	Red marl			4	2	0	27	5	0
15	Hard red conglomerate			3	1	0	3	1	0
16	Red metal with red post gorlits			5	4	8			
17	Blue metal			3	3	11			
18	Red & Blue metal			2	4	0	11	0	7
19	Fire clay								
20	Blue metal			0	2	2			
				0	3	4			
21	Grey metal stone			3	3	3			
22	Grey post								
23	Blue metal			2	4	4			
24	Grey metal stone								
25	Blue metal								
26	Grey metal stone			2	1	11			
27	Black metal			0	3	2			
28	Fire clay			0	0	8			
29	Blue metal			1	1	2			
30	Grey post			0	2	7			
31	Blue metal			0	0	9			
				1	2	7			
32	Grey metal stone			0	4	6			
				3	0	0			
33	Blue metal								
34	Grey metal stone			3	4	0			
35	Black Metal								
36	Blue Metal								
37	Fire clay								
38	Grey metal stone			0	1	2			
39	Grey post called "Rice greys" with soft partings			0	2	6			
				1	4	3			
				0	3	6			
40	Grey metal stone								
41	Grey post								
42	Black metal								
43	Grey post			7	0	8			
44	Blue metal			0	5	7			
45	Coal CREAT VEIN			0	2	9			
46	Fire Clay								
47	Black metal								
48				2	3	6	38	3	8
				0	0	9			
49	Grey metal Stone								
50	Coal TOP LITTLE VEIN (from the top)			0	3	6	6	4	4½
51	Rone Coal			0	2	6½	0	2	4½
52	Grey metal stone								
53	Dark grey post			2	4	0			
54	Grey post with coal partings			1	0	0			
55	Grey post								
56	Blue metal			2	0	0			
57	Black metal with ironstone pebbles			0	4	0			
58	Grey post								
59	Blue metal			1	3	0			
60	Coal MIDDLE VEIN (from the overlay)			0	3	4			
61	Bastil			0	3	10½	0	1	10½
62	Fire Clay								
63	Black metal			3	3	11			
64	Grey metal stone			2	0	2			
65	Grey post			5	2	6			
66	Coal TOP LITTLE VEIN (from the overlay)								
67	Fire clay			0	4	2	13	5	3½
				1	0	6			
68	Grey post								
69	Dark grey post								
70	Grey coal								
71	Dark grey post								
72	Grey post								
73	Grey coal								
74	Soft Black metal								
75	Blue metal								
76	Coal MIDDLE VEIN (from the overlay)								
77	Fire clay								
				1	5	0	8	4	7
78	Grey post			0	3	0			
79	Blue metal								
80	Fire clay								
81	Blue metal			2	0	8			
				1	1	11½			
82	Grey metal stone								
83	Fire clay								
84	Grey post			3	2	5			
85	Blue metal								
86	Grey post			3	1	6			
87	Grey metal stone			0	3	0			
				1	3	4			
				0	3	4			
88	Grey post								
89	Blue metal								
90	Black ⎫								
91	Coal ⎬								
92	Coal Bone ⎭								
93	Fire clay			3	1	6			
				0	2	6			
				0	1	2			
				0	2	2½			
				0	2	10½			
	SLYONG VEIN.								
94	Blue metal								
95	Coal								
96	Fire clay								
97	Black metal								
98	Fire clay			2	0	10	22	4	0
100	Grey post			5	2	7			
101	Blue metal			1	0	9			
102	Grey post								
103	Blue metal			1	0	0			
104	Grey post			4	3	6			
105	Blue metal			0	3	4			
106	Black								
107	Coal BOTTOM LITTLE VEIN			1	0	8			
108	Fire clay								
109	Grey post			4	3	6			
110	Blue metal			0	1	3	6	2	6
				0	4	0			
111	Grey post			0	0	6			
112	Blue metal			1	3	2			
113	Coal BULL VEIN								
114	Fire clay								
				2	2	6	4	4	6
				0	3	0	0	3	0
			Total				102	2	8½

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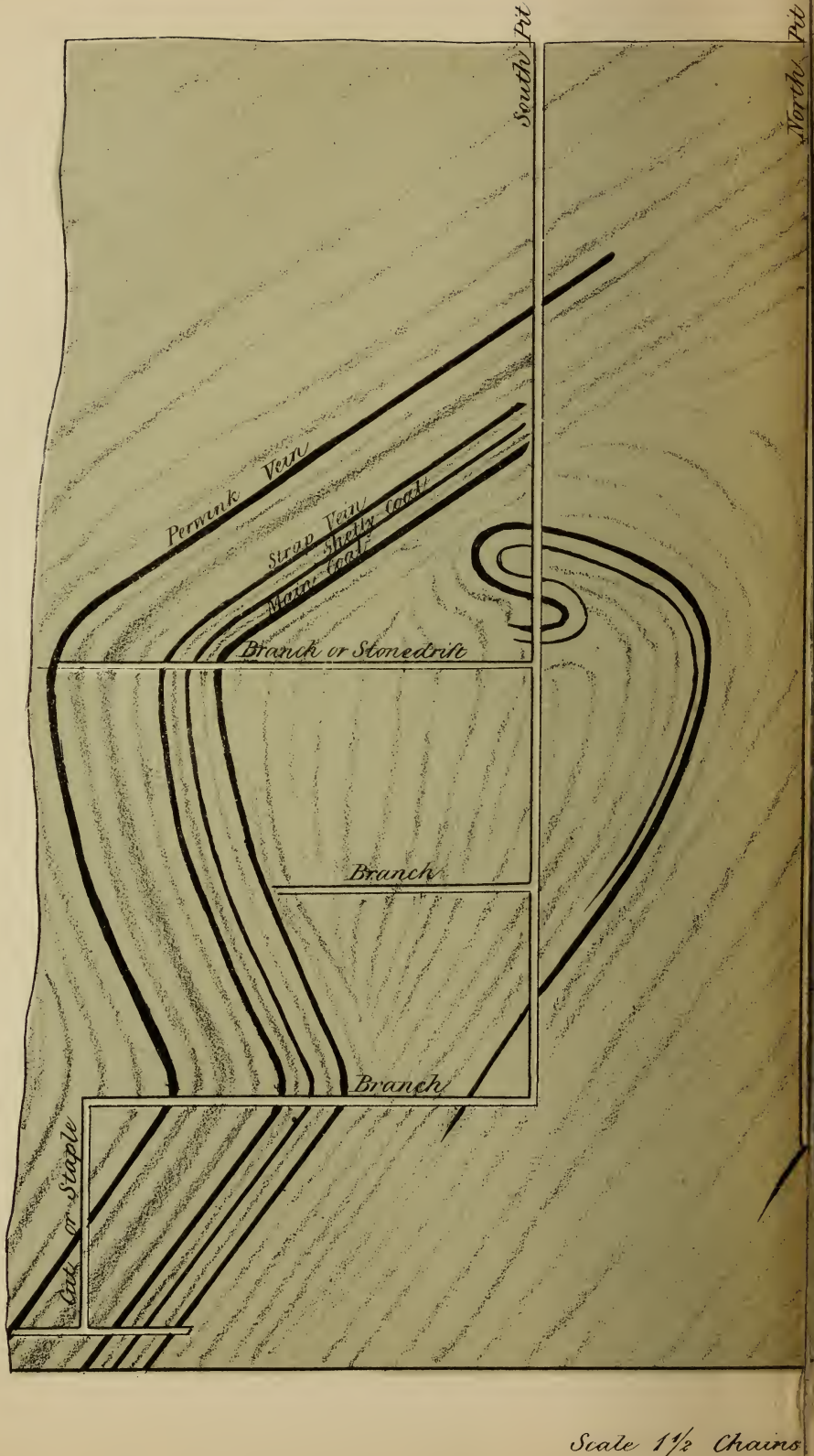

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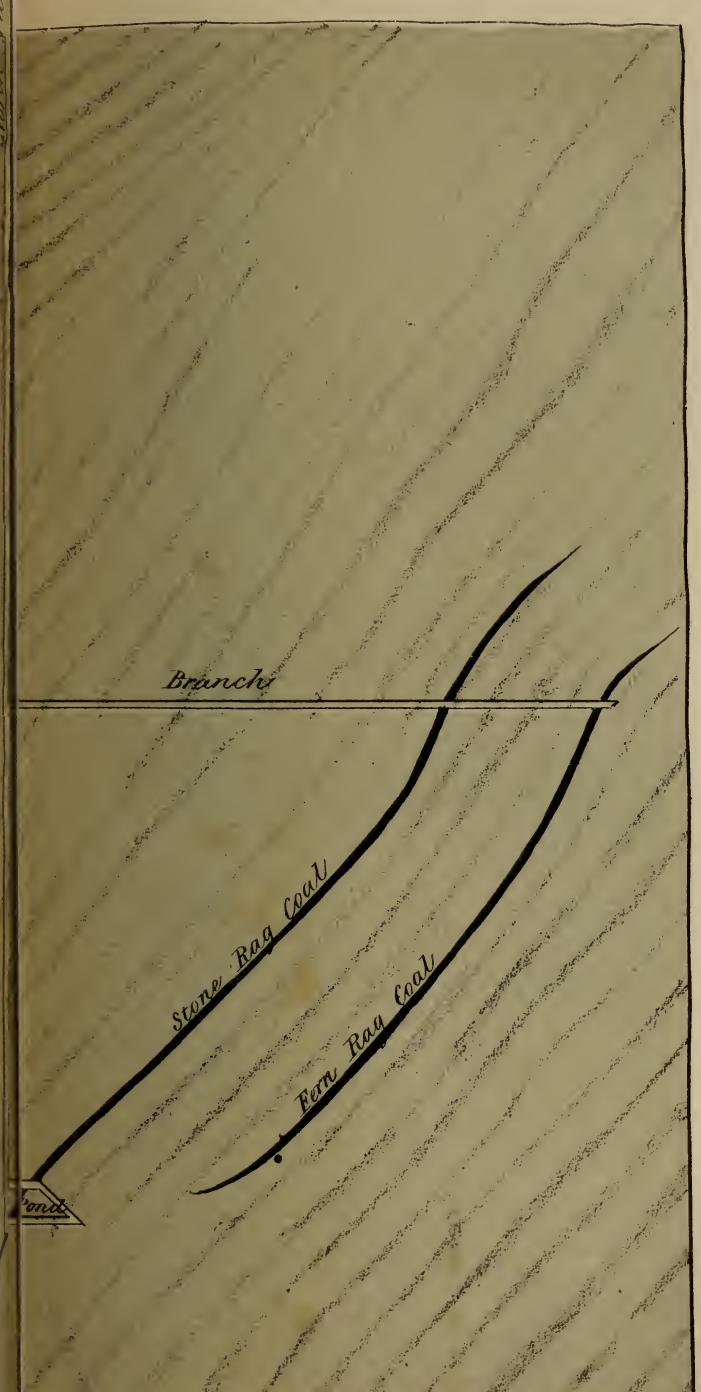

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there were about 3,000 feet of coal measures and Grit Rock below, making a total of about 9,000 feet above the Mountain Limestone. In North Staffordshire, the upper and middle sections alone were 6,000 feet, and that below is about 3,000 feet, without including the Grit. This shewed that there were in this country coal fields quite equalling in thickness the Somersetshire coal field. He mentioned this, because he thought it important in a geological point of view. As regarded the Fossil Flora, he observed it abounded in various parts of the sections, and that he had not found in any coal field with which he was acquainted, any plant that could be taken to identify any particular stratum in the series. In Lancashire there was a particular shell, called the Goniatite, very similar to the Ammonite, which was never found above a particular coal in the basin. This he considered a most useful mark, and he thought it would be well to know whether the same thing existed in the South Wales and Somersetshire districts

The PRESIDENT said that no one present could fail to be pleased with, and obliged, for this most interesting paper. We were, he feared, too little acquainted with the mode in which these veins of coal could be worked. It seemed strange that the Radstock coal, averaging little more than 18 inches thick, could be worked more cheaply than we could work our South Wales coal, which, in many cases, is 10 feet thick. The Somersetshire district owed much to the author of this paper for moving on in the application of the most skilful methods of working the thin seams of coal. The Institute would be glad to get from Mr. Greenwell a paper on the working of this coal, and he thought it would be found that we had, in this district, been sadly negligent in cultivating our knowledge as to this matter. Mr. Greenwell deserved our most cordial thanks for his excellent paper: he had kindly promised a paper on the Wiltshire Iron Ore, which the Institute would no doubt be glad to accept.

Mr. BASSETT had much pleasure in proposing a vote of thanks to Mr Greenwell, and hoped to have, at a future meeting, another paper giving us the cost and system of working the Somersetshire coals. We in South Wales were strangers to the working of thin coals, and a paper on the subject would be very valuable to the Institute.

Mr. CLARK seconded the motion of Mr. Bassett.

The SECRETARY then read the following paper:—

MEMORANDA ON "BRUNTON'S VENTILATING FAN," AS APPLIED AT CWMSAERBREN COLLIERY.

By Mr. H. HUXHAM, Pontypridd.

Whilst presenting the Institute with the following memoranda on this important subject, it cannot but be regretted that the information should be of so imperfect a character.

The workings of this colliery are, however, at present, in an unfavourable condition for attaining a correct estimate of the value of this appliance, as a ventilating power. The Fan, also, is of imperfect construction, and is not in the best working order.

I have endeavoured to procure Mr. William Brunton's treatise "On the Ventilation of Coal Mines," published in 1849, in which, as he states elsewhere, a full and detailed description of the application of his fan, for the purposes of ventilation, will be found. I have, however, been unsuccessful. This I much regret, as it was my wish to have laid *his* views on this subject fully before you.

Many of the members present, no doubt, will remember his lecturing at Dowlais, in the latter part of 1849, when he powerfully advocated the claims of his fan as a ventilating power. His models were good, and certainly produced results, such as to justify a fair trial of his fan in *practice.*

The only record I have of Mr. Brunton's calculations and data, with respect to his ventilating Fan, I here transcribe:—

"Improved Method of Ventilating Collieries, by Wm. Brunton,
"C.E., Newport, Mon.

"For colliery purposes he constructs over the upcast pit, or "over a chamber connected therewith, a hollow drum, with radial

"compartments, through which the air is discharged with that de-
"gree of force due to the velocity with which the drum revolves.

"The diagrams A and B (fig. 1.) represent a drum, 22 feet ex-
"terior diameter, with radial compartments of 6 feet long each, and
"revolving at any required velocity.

"Taking 16 feet as the mean diameter of the compartments, the
"centrifugal force, at 120 revolutions, will be 39.25, which, multi-
"plied by the weight of 6 cubic feet of air, $=\frac{474}{1000}$ of a pound, will
"give a pressure of 17.5 lbs. on the square foot, as the amount of
"rarefaction produced, which is three times as much as is obtained
"by the best furnace:—When the drum revolves

"	60	times per minute, the rarefaction is		4.3	lbs. on square feet.
"	90	"	"	9.7	"
"	120	"	"	17.3	"
"	150	"	"	27.0	"
"	180	"	"	39.0	"
"	210	"	"	53.0	"

"The machine is an entirely new modification of the Fan. Its
"construction is of the most simple integral character; it has no
"valves or separate moving parts; has no attrition; and all the
"friction is resolved into a foot pivot moving in oil; when at rest
"offers no impediment to air ascending from the shaft; is very in-
"expensive, and liable to no derangement; in short, it is a simple
"mechanical implement, whereby any degree of rarefaction neces-
"sary to ventilation is rendered certain and regular, being subject
"to the law of central forces, which is as fixed and determined as
"that by which a stone falls to the earth.

"But beyond the ordinary requirements of ventilation, as now
"practised, there is an advantageous application of this machine,
"which can in no respect be effected or imitated by the furnace.
"It possesses such power of rarefaction that the atmosphere of a
"colliery may be subjected in half an hour to an artificial exhaus-
"tion of ·3, ·4, or ·5 of an inch of mercury; producing in the col-
"liery, during the absence of the workmen and their lights, the
"very same exudation of the gases that would have taken place

"during the natural change of the atmosphere indicated by a like "fall of the barometrical column; and before the men re-enter the "mine, the machine will discharge the noxious gas by a current of "fresh air more copious and effective than can be produced by any "other means in use.

"'Colliery Inspection.—On Wednesday, the 29th of August, "'J. K. Blackwell, Esq., the Government Inspector of Mines, "'visited Gellygaer, the colliery of Thomas Powell, Esq. (the Gaer "'near Newport), and examined the mechanism, and witnessed the "'performance of the ventilator erected there by Mr. Brunton, "'for the proprietor, who, together with Mr. Rogers of Abercarn, "'Mr. James of Woodfield, Mr. Thomas Williams, &c., accom- "'panied the inspector through the colliery. The rarefaction "'maintained by the machine being fully 2 inches of water, or "'10 lbs. on the square foot, was found more than sufficient for the "'ventilation of this, one of Mr. Powell's minor collieries, but "'selected by himself purposely, to ascertain the capability of this "'novel apparatus, before his application of it to his other extensive "'works. After traversing the extent of the workings, in an "'abundant supply of air, the party retired into the bottom of the "'downcast shaft, when the most interesting part of the performance "'was exhibited by shutting the inlet air door, which was instantly "'followed by a loud rushing of the air through all the crevices of "'the door and stoppings, and during the application of the water- "'gauge (not more than a minute), the whole extent of the colliery, "'6 or 8 acres, was thus artificially subjected to the same circum- "'stances as if, by a natural atmospheric change, the barometer "'had fallen ·2 of an inch; leaving no doubt as to the practicability "'of exhausting a colliery to ·3, ·4, or ·5, if needful; thereby draw- "'ing off the fire-damp, or other gases, during the absence of the "'workmen. And as a further demonstration of the capability of "'discharging the gas thus drawn out, and of restoring fresh air, "'the velocity of the machine was increased till the rarefaction was "'$4\frac{3}{4}$ inches of water, or 24 lbs. on the square foot. This machine "'being satisfactorily tested, is to be removed to the Old Duffryn

"'Colliery, another put up upon the New Duffryn Colliery, and in "'a few weeks, one will be in operation at Gyfyllion Colliery, be-"'longing to Mr. J. Calvert, (Monmouthshire Merlin.)'"

I find, from inquiry, that the ventilator now at work at Cwmsaerbren Colliery, is identical with that mentioned in the preceding notice, as about to be put up at Gyfyllion Colliery, by Mr. J. Calvert: it was constructed under the immediate superintendance of Mr. Brunton, at the Newbridge Chain Works, Pontypridd.

When first the working of the coal was commenced at Cwmsaerbren Colliery, a very large quantity of gas, in a high state of tension, was given off, so as to render it difficult, if not positively dangerous, to attempt to open the workings with furnace ventilation. Finding this to be the case, Mr. W. S. Clark, who conducted the winning for the Trustees of Lord Bute, determined on using a safer mode of ventilation. Finding this ventilator lying unused at Messrs. Brown, Lenox, & Co.'s Works, and having, some time previously, been looking into the subject with Mr. Brunton, and impressed with its value as a temporary expedient, he resolved to give it a trial at Cwmsaerbren, and accordingly had it put up.

The principal dimensions of this Fan (Figs. 2 and 3) are,

Outside diameter of Fan	20 feet.
Inside ditto	8 „

Number of radial compartments, 24.

Length of compartments	6 feet.
Area of each compartment at inside opening, or where the air from the mine enters	3.05 sup. ft.
Area of each compartment at outside opening, or where the air is expelled from the circumference of Fan	3.04 sup. ft.
Depth of compartments, at inside	2 ft. 10 ins.
Ditto at outside	1 ft. 2 ins.
Length of Spindle	7 ft. 3 ins.
Diam. of do.	5 ins.

It is worked by a direct-action, high-pressure, horizontal engine.

Diameter of Cylinder	16 ins.
Length of Stroke	34 ins.
Pressure of steam on boilers (average)....	40 lbs.

The steam is brought in 3 inch pipes, from the boilers of the winding engine.

In the diagrams of the Fan, and Upcast pit, as shewn in Figs. 2 and 3 :—

A, represents the Upcast Shaft.

D, the Drift communicating with ditto.

B, the Ventilating Fan.

C, the Radial Compartments.

E, the Central, or inside space, through which the air enters the Fan.

F, the Circumference, at which the air is expelled.

G, the Spindle of Fan, resting and revolving in cast-iron cup H, securely bolted to beam I, and supported by bearings at K, in bed-plate L, bolted to girders M and M. A crank N is keyed on to end of spindle G, and connected directly with steam cylinder at O, the slide valve (O,) of which, is worked by an eccentric P, by means of a short weigh-bar and lever Q.

The Upcast Shaft A is of an elliptic form, 10 ft. × 7 ft., 3 ft. of one end being nearly taken up with the pumps, leaving about 45 sup. ft. for effectual ventilating area.

The downcast shaft is circular, 12 feet 6 inches diameter in the smallest part.

The upcast and downcast shafts are each 130 yards deep.

Length of drift D from upcast to ventilator is 15 yards, with an average area of over 50 feet sup.

In 1855 I made some experiments on the power of this Fan. The underground workings were then of very limited extent, being

represented by a total length of air-course of only 1035 yards, divided thus :—

a.—Downcast pit, average area 123 sup. ft. ...	130 yds.
b.—Distance to place where the air was split, average area 58 sup. ft.....	143 „
c.—Length of air-course of dip split, until it joined the main split, average area 30 ft.	275 „
d.—Length of air-course of main split, to rise workings, until joined by dip split, average area 35 ft.	22 „
e.—Air-course, from junction of splits to bottom of upcast, average area 36 ft.	320 „
f.—Upcast pit, average area 45 ft.....	130 „
g.—Drift from Upcast to Ventilator, average area 50 ft.	15 „
Total yards for air to travel	1035 yds.

The following table (1) contains the results of the experiments then made, the revolutions of the Fan being from 50 to 60 per minute :—

OF AIRCOURSES.		QUANTITY OF AIR.					POWER.	
Aircourses 30 average area, 30 feet.	Aircourses *b* & *e*, average area, 40 feet.	Total average area, 36 feet.	Aircourse *d*, ℔ minute.	Aircourse *c*, ℔ minute.	Main Intake (*b*) ℔ minute.	Main Return (*c*) ℔ minute.	Natural Ventilation.	In lbs. pressure per square foot in upcast, as indicated by Water Gauge.	Horse power utilized in Upcast.
ls.	Yards.	Yards.	C. Ft.	C. Ft.	C. Ft.	C. Ft.	C. Ft.	Lbs.	H. P.
5	463	1035	17,100	6,768	23,780	23,900	3,800	8.28	5.969
	...	...	16,200	5,450	21,600	21,650	...	7.20	4.722
	...	...	14,750	3,900	18,730	18,720	...	6.06	3.429
	...	530	...	...	34,447	34,450	...	8.28	8.637

ng through Brattices.

d with safety, and even then, that this speed could not be continued for any

orking limit of this Fan, it appears that the mean results, are as shewn

TABLE I.

Depth of downcast, 130 yards, average area, 123 feet. Depth of upcast, 130 yards, average area, 45 feet.	TEMPERATURE.				BAROMETER.						VELOCITY OF AIR.				LENGTH OF AIRCOURSES.				QUANTITY OF AIR.					POWER.	
	Downcast at Bank.	Downcast at Bottom.	Upcast at Bottom.	Upcast at Top.	Downcast at Bank.	Downcast at Bottom.	Upcast at Bottom.	Water Gauge.	Pressure of Steam.	Revolutions of Fan, ℣ minute.	Aircourse *a*, average area, 123 feet.	Aircourse *f*, average area, 45 feet.	Aircourse *c*, average area 30 feet.	Aircourse *d*, average area, 36 feet.	Aircourse *d*, average area, 36 feet.	Aircourse *e*, average area, 30 feet.	Aircourses *b* & *e*, average area, 40 feet.	Total average area, 36 feet.	Aircourse *d*, ℣ minute.	Aircourse *c*, ℣ minute.	Main Intake (*b*) ℣ minute.	Main Return (*c*) ℣ minute.	Natural Ventilation.	In lbs. pressure per square foot in upcast, as indicated by Water Gauge.	Horse power utilized in Upcast.
	Deg.	Deg.	Deg.	Deg.	Ins.	Ins.	Ins.	Ins.	Lbs.	No.	Ln. Ft.	Ln. Ft.	Ln. Ft.	Ln. Ft.	Yards.	Yards.	Yards.	Yards.	C. Ft.	C. Ft.	C. Ft.	C. Ft.	C. Ft.	Lbs.	H. P.
Experiment 1	54	54	60	57	29.72	30.09	30.00	1.38	40	60	193	531	225	475	22	275	463	1035	17,100	6,768	23,780	23,900	3,800	8.28	5.969
" 2	...	...	...	...	...	...	...	1.20	41	55	175	481	181	450	...	...	...	...	16,200	5,450	21,600	21,650	...	7.20	4.722
" 3	...	...	...	...	...	...	...	1.01	40	50	152	415	130	410	...	...	...	...	14,750	3,900	18,730	18,720	...	6.06	3.429
" 4 (No. 4, with the main seperation doors open.)	...	...	...	...	...	...	...	...	40	60	280	765	...	...	...	...	...	530	...	...	34,447	34,450	...	8.28	8.637

NOTE.—The Airways generally in good order,—the air much contracted, however, in passing through Brattices.

It was found, from the imperfect construction of the Fan, that a greater velocity than sixty revolutions per minute could not be attained with safety, and even then, that this speed could not be continued for any length of time.

From a series of experiments, with the Fan working at forty revolutions per minute, which rate I found to be the practical continuous working limit of this Fan, it appears that the mean results, are as shewn in the annexed Table (2)—

F AIRWAYS.		QUANTITY OF AIR.					POWER.	
Aircourse *c*, average area, 30 feet.	Total, average area, 36 feet.	Aircourse *d*, ℔ minute.	Aircourse *c*, ℔ minute.	Main Intake (*b*) ℔ minute.	Main Return (*c*) ℔ minute.	Natural Ventilation.	In lbs. pressure per square foot in upcast, as indicated by Water Gauge.	Horse power utilized in Upcast.
Yards.	Yards.	C. Ft.	C. Ft.	C. Ft.	C. Ft.	C. Ft.	Lbs.	H. P.
275	1035	13,210	4,310	17,520	17,530	3,900	4.38	2.275
...	...	13,116	3,920	17,000	17,040	...	4.26	2.196
...	...	13,763	4,230	17,800	17,990	...	4.68	2.543
...	...	12,250	3,850	16,100	16,140	3,850	4.02	1.962
...	...	12,310	3,900	16,150	16,210	...	4.08	2.003
...	530	...	...	25,800	25,850	...	4.50	3.522

TABLE II.

Depth of downcast, 130 yards, average area, 123 feet. Depth of upcast, 130 yards, average area, 45 feet.	TEMPERATURE.				BAROMETER.						VELOCITY OF AIR.				LENGTH OF AIRWAYS.				QUANTITY OF AIR.					POWER.	
	Downcast at Bank.	Downcast at Bottom.	Upcast at Bottom.	Upcast at Top.	Downcast at Bank.	Downcast at Bottom.	Upcast at Bottom.	Water Gauge.	Pressure of Steam.	Revolutions of Fan, ☤ minute.	Aircourse *a*, average area, 123 feet.	Aircourse *f*, average area, 45 feet.	Aircourse *c*, average area 30 feet.	Aircourse *d*, average area, 36 feet.	Aircourse *d*, average area, 36 feet.	Aircourses *b* & *e*, average area, 40 feet.	Aircourse *c*, average area, 30 feet.	Total, average area, 36 feet.	Aircourse *d*, ☤ minute.	Aircourse *c*, ☤ minute.	Main Intake (*b*) ☤ minute.	Main Return (*c*) ☤ minute.	Natural Ventilation.	In lbs. pressure per square foot in upcast, as indicated by Water Gauge.	Horse power utilized in Upcast.
No. of experiments.	Deg.	Deg.	Deg.	Deg.	Ins.	Ins.	Ins.	Ins.	Lbs.	No.	Ln Ft.	Ln. Ft.	Ln. Ft.	Ln. Ft.	Yards.	Yards.	Yards.	Yards.	C. Ft.	C. Ft.	C. Ft.	C. Ft.	C. Ft.	Lbs.	H. P.
1	50	52	59	55	29.63	30.02	29.97	.73	38	40	142	381	143	367	22	463	275	1035	13,210	4,310	17,520	17,530	3,900	4.38	2.275
2	...	...	...	...	...	...	...	.71	39	40	138	378	130	364	...	...	...	...	13,116	3,920	17,000	17,040	...	4.26	2.196
3	...	...	...	...	...	...	...	.78	38	40	144	399	141	382	...	...	...	...	13,763	4,230	17,800	17,990	...	4.68	2.543
4	56	56	62	60	29.54	29.91	29.90	.67	40	40	131	358	128	340	...	...	...	...	12,250	3,850	16,100	16,140	3,850	4.02	1.962
5	...	...	...	...	...	...	...	.68	40	40	131	360	130	342	...	...	...	...	12,310	3,900	16,150	16,210	...	4.08	2.003
6 { Main separation doors open. }	...	...	...	...	...	...	...	...	40	...	210	574	...	...	...	...	...	530	...	...	25,800	25,850	...	4.50	3.522

NOTE.—The air passages much contracted by Brattices in winning drifts.

In 1856 and 1857 I made some further experiments, the results of which will be found in the annexed Table (3):—

	RWAYS.		QUANTITY OF AIR.					POWER.	
Depth of downcast, 130 yards, average area, 123 feet.	Aircourse *b* & *e*, average area, 50 feet.	Total, average area, 38 feet.	Aircourse *d*, ℔ minute.	Aircourse *e*, ℔ minute.	Main Intake (*b*) ℔ minute.	Main Return (*e*) ℔ minute.	Natural Ventilation.	In Hbs. pressure per square foot in upcast, as indicated by Water Gauge.	Horse power utilized in Upcast.
o. of experi	rds	Yards	C. Ft.	C. Ft.	C. Ft.	C. Ft.	C. Ft.	Lbs.	H. P.
1—Dec.	33	2177	15,884	6,460	22,300	22,444	4,100	3.18	2.168
2—Jan.	33	2485	12,400	7,540	19,950	20,100	3,910	3.00	1.824
3—June	33	4258	14,760	10,000	24,240	24,800	3,850	3.42	2.569
4—July	33	4858	16,640	9,780	25,970	26,420	4,430	3.84	4.637
5	..	...	...	...	...	10,800	3,950	1.26	...
6	..	...	15,790	8,450	24.450	24,540	4,150	3.66	...
7	..	...	16,740	8,780	24,980	25,520	4,150	3.72	...

order.

Since carefully noticed the ventilation.

The

As t port, are now presented, with regard to the efficiency of this Fan, as a manen

At th ower of the Fan, is very considerably reduced, from the results shewn the pr e offered to the air in its passage through the mine—although, I would nark, th

TABLE III.

Depth of downcast, 130 yards, average area, 123 feet. Depth of upcast, 130 yards, average area, 45 feet.	TEMPERATURE.				BAROMETER.						VELOCITY OF AIR.				LENGTH OF AIRWAYS.				QUANTITY OF AIR.					POWER.	
	Downcast at Bank.	Downcast at Bottom.	Upcast at Bottom.	Upcast at Top.	Downcast at Bank.	Downcast at Bottom.	Upcast at Bottom.	Water Gauge.	Pressure of Steam.	Revolutions of Fan, ℣ minute.	Aircourse *a*, average area, 123 feet.	Aircourse *f*, average area, 45 feet.	Aircourse *c*, average area, 30 feet.	Aircourse *d*, average area, 36 feet.	Aircourse *d*, average area, 36 feet.	Aircourses *c*, average area, 30 feet.	Aircourse *b* & *e*, average area, 50 feet.	Total, average area, 38 feet.	Aircourse *d*, ℣ minute.	Aircourse *c*, ℣ minute.	Main Intake (*b*) ℣ minute.	Main Return (*e*) ℣ minute.	Natural Ventilation.	In lbs. pressure per square foot in upcast, as indicated by Water Gauge.	Horse power utilized in Upcast.
No. of experiments.	Deg.	Deg.	Deg.	Deg.	Ins.	Ins.	Ins.	Ins.	Lbs.	No.	Ln. Ft.	Ln. Ft.	Ln. Ft.	Ln. Ft.	Yards	Yards	Yards	Yards	C. Ft.	C. Ft.	C. Ft.	C. Ft.	C. Ft.	Lbs.	H. P.
1—Dec. 1856.	37	42	60	55	29.80	30.16	30.10	.53	39	35	181	500	215	441	968	671	263	2177	15,884	6,460	22,300	22,444	4,100	3.18	2.168
2—Jan. 1857.	35	39	58	53	29.43	29.80	29.80	.50	38	30	161	446	251	344	1122	825	263	2485	12,400	7,540	19,950	20,100	3,910	3.00	1.824
3—June, 1857	58	56	63	59	29.56	29.94	29.90	.57	40	35	197	551	333	410	2530	1190	263	4258	14,760	10,000	24,240	24,800	3,850	3.42	2.569
4—July, 1857.	54	55	61	58	29.63	29.99	29.94	.64	40	40	211	587	326	462	2970	1350	263	4858	16,640	9,780	25,970	26,420	4,430	3.84	4.637
5 "	...	...	...	...	...	...	...	.21	39	13	...	218	...	...	...	...	...	...	...	...	...	10,800	3,950	1.26	...
6 "	...	...	...	...	...	...	...	.61	40	35	196	545	281	436	...	...	...	...	15,790	8,450	24.450	24,540	4,150	3.66	...
7 "	...	...	70	61	...	...	...	.62	40	30	203	567	293	465	...	...	...	...	16,740	8,780	24,980	25,520	4,150	3.72	...

NOTE.—No. 7, with a small fire lamp, additional, at bottom of upcast.—Airways in good order.

Since the experiments exhibited in table 3 were made, the management of the Colliery has passed into other hands; and, consequently, I have not so carefully noticed the ventilation.

The Fan has now been at work for upwards of 3 years, during which time it has been continuously used as the ventilating power of the Colliery.

As the workings of the Colliery have been extended very considerably during the last twelve months, many features, of valuable practical import, are now presented, with regard to the efficiency of this Fan, as a permanent ventilating power.

At the present time, as will be seen from the following tabulated results of experiments made early in October of this year, the effective ventilating power of the Fan, is very considerably reduced, from the results shewn in the previous tables;—this I attribute, principally, to the present very contracted airways of extended lengths—in fact, to the extra "drag," or resistance offered to the air in its passage through the mine—although, I would remark, the water-gauge would hardly indicate such a great difference.

No. of experiment	Depth of downcast, 130 yards, average area, 123 feet. Depth of upcast, 120 [illegible]	F AIRWAYS. Aircourse *b* & *e*, average area, 50 feet.	F AIRWAYS. Total, average area, 30 feet.	QUANTITY OF AIR. Aircourse *d*, ℔ minute.	QUANTITY OF AIR. Aircourse *c*, ℔ minute.	QUANTITY OF AIR. Main Intake (*b*) ℔ minute.	QUANTITY OF AIR. Main Return (*e*) ℔ minute.	QUANTITY OF AIR. Natural Ventilation.	POWER. In lbs. pressure per square foot in upcast, as indicated by Water Gauge.	POWER. Horse power utilized in Upcast.
		Yards	Yards	C. Ft.	C. Ft.	C. Ft.	C. Ft.	C. Ft.	Lbs.	H. P.
1—Fan [illegible]		263	6,938	9,320	6,200	14,960	15,550	5,200	4.86	2.287
2—Fire		...	...	6,250	4,100	9,970	10,400	...	3.18	1.001
3—Fan [illegible]		...	...	9,710	6,115	15,240	15,870	...	4.92	2.361
4—Fire		...	...	6,110	4,700	10,320	10,850	...	3.36	1.196
5 Fire dam down—f stationa		...	...	...	...	6,120	6,500	...	1.50	0.367

[illegible]out 12 cwt. of coal in 24 hours.

TABLE IV.

Depth of downcast, 130 yards, average area, 123 feet. Depth of upcast, 130 yards, average area, 45 feet.	TEMPERATURE.				BAROMETER.						VELOCITY OF AIR.				LENGTH OF AIRWAYS.				QUANTITY OF AIR.					POWER.	
	Downcast at Bank.	Downcast at Bottom.	Upcast at Bottom.	Upcast at Top.	Downcast at Bank.	Downcast at Bottom.	Upcast at Bottom.	Water Gauge.	Pressure of Steam.	Revolutions of Fan, ℣ minute.	Aircourse *a*, average area, 123 feet.	Aircourse *f*, average area, 45 feet.	Aircourse *c*, average area, 25 feet.	Aircourse *d*, average area, 30 feet.	Aircourse *d*, average area, 30 feet.	Aircourses *c*, average area, 25 feet.	Aircourse *b* & *e*, average area, 50 feet.	Total, average area, 30 feet.	Aircourse *d*, ℣ minute.	Aircourse *c*, ℣ minute.	Main Intake (*b*) ℣ minute.	Main Return (*e*) ℣ minute.	Natural Ventilation.	In lbs. pressure per square foot in upcast, as indicated by Water Gauge.	Horse power utilized in Upcast.
No. of experiments.	Deg.	Deg.	Deg.	Deg.	Ins.	Ins.	Ins.	Ins.	Lbs.	No.	Ln Ft.	Ln. Ft.	Ln. Ft.	Ln. Ft.	Yards	Yards	Yards	Yards	C. Ft.	C. Ft.	C. Ft.	C. Ft.	C. Ft.	Lbs.	H. P.
1—Fan & Fire	49	50	84	62	29.53	29.92	29.87	.82	40	35	122	345	248	311	4,500	1,900	263	6,938	9,320	6,200	14,960	15,550	5,200	4.86	2.287
2—Fire Only	...	...	...	...	...	...	...	.53	...	...	81	231	164	208	...	...	...	...	6,250	4,100	9,970	10,400	...	3.18	1.001
3—Fan & Fire	...	...	...	...	...	...	...	.82	40	35	124	352	244	323	...	...	...	...	9,710	6,115	15,240	15,870	...	4.92	2.361
4—Fire Only	...	...	...	...	...	...	...	.56	...	...	84	261	188	203	...	...	...	...	6,110	4,700	10,320	10,850	...	3.36	1.196
5 Fire damped down—fan stationary.	48	50	68	58	29.60	29.97	29.96	.25	...	...	50	180	...	...	...	...	...	...	...	...	6,120	6,500	...	1.50	0.367

NOTE.—Airways, of long lengths, much contracted.—Large fire-lamps, at bottom of upcast, consuming about 12 cwt. of coal in 24 hours.

From the 4th experiment in Table 1, it would appear that the maximum useful effect attained by the Fan, whilst making 60 revolutions per minute, and drawing the air through a channel 530 yards long, having an average area of 60 sup. ft. (the main separation doors being open), was 8.637 horse power, moving a volume of 34,450 c. ft. of air per minute through the upcast shaft, at a velocity of 765 ft. per minute, or 12.75 per second; but 3,800 c. ft. of this air is due to the natural ventilation, leaving, therefore, 30,650 c. ft. due to the effect of the Fan, with a practical utilization of 8 horse-power.

The Fan being driven by a direct-action horizontal steam cylinder of 16 inches diameter, and 34 inches stroke, with steam at 40 lbs. pressure, would represent, as being directly employed in producing the above results, a power of..... 23.757 h. p.

Deduct, therefore, power utilized 8.00

We have a loss of..... 11.757

equal to 66.32 per cent.

Again, experiments Nos. 1, 2, and 3, shew respectively a loss of 77.40, 81.10, and 84.27 per cent. of the power applied.

In table 2, experiment No. 1 shews a loss of 86.91 per cent.

„ 3, „ 2 „ 86.35 „

„ „ „ 3 „ 83.65 „

„ „ „ 4 „ 74.30 „

From table 4, it would appear that the total ventilation, at present, is .....15,550 c. ft.

Of which quantity the fire-lamp, together with the natural ventilation, produces .....10,400 „

Leaving only ..... 5,150 c. ft.

per minute, as being due to the effect of the Fan. This is such a very small amount, that it was with considerable hesitation I noted it down, thinking most probably I had made an error. In reproducing the experiment, however, as shewn at Nos. 3 and 4, the results were so nearly the same, that I have no doubt the figures are correct. The only explanation I can offer for this small

amount, in comparison with the other tables, is that possibly there may have been some leakage, admitting air from the surface to the Fan, which escaped my notice.

It would, therefore, appear from a comparison of the tables, that the effective power of the Fan decreases very rapidly with every increase in the "drag," or resistance to the air through the mine, as indicated by the water-gauge, for we have in

		W.-guage.			
Table 1,	60 rev. of Fan, with	1.38	a volume of	20,100	c. ft. as quantity of air exhausted by *Fan.*
„	„ 55	do.	1.20	do.	17,850
„	„ 50	do.	1.01	do.	14,920
„	2, 40	do.	0.73	do.	13,630

shewing an increase to the rarefaction produced, of about .195 lbs. per sqr. ft. for every additional revolution of the Fan, over 40 up to 60; and an increase to the quantity of air exhausted from the mine of 513 c. ft. for every additional revolution of the Fan from 50 to 60 rev., and an increase of 129 c. ft. every additional revolution from 40 to 50 per minute. Again we have in

Table 3,	40 rev. of Fan, with	.64	water-gauge,	21,990	c. ft. of air exhausted per minute by the *Fan.*
„	35	do.	.57	„	20,950
„	30	do.	.50	„	16,190

This shews an increase of .085 lbs. pressure per sqr. ft., and 580 c. ft. in quantity of air exhausted, for every additional revolution of the Fan, from 30 to 40 rev. per minute.

In Table 1, the airways were of good size, contracted only whilst passing through the bratticing in the winning drifts. In Table 2, a portion only, of the air, was allowed to course through the brattices.

In Table 3, the airways were good, and but very few contractions existed.

In Table 4, the airways were of an average size of 30 sup. ft., but the air was very much contracted in places, for considerable lengths; the air-courses generally not being in good repair.

These various conditions, existing when the experiments were made, will, perhaps, in some degree account for the discrepancies,

shewn above, to exist between the *speed* of the *Fan;* the *resistance* to be overcome by the air in its passage through the mine; and the *useful effect* of the ventilator, as shewn by the number of c. ft. of air exhausted per minute.

With the main separation doors open, we have from

	Rev. per min.	Veloc. in upcast per min.	Quantity of air exhausted per min.
Table 1	60	765 ft.	34,450 c. ft.
„ 2	40	574 ft.	25,850 „

or an increment of 430 c. ft. of air, for every additional revolution of the Fan per minute.

It will, perhaps, be useful to compare the theoretical value of this Fan, as set forth by Mr. Brunton, with the practical effect as adduced from the preceding tables. According to Mr. Brunton, when the Drum, or Fan, revolves at

60	rev. per min., the rarefaction is	4.3	lbs. per sqr. ft.
90	„	9.7	„
120	„	17.3	„
150	„	27.0	„

From the tables we have,

Table 1,	60	revolutions, producing	8.05 lbs.	average pressure per sqr. ft. due to ventilator.
„	55	„	7.00	
„	50	„	5.72	
„	40	„	4.17	
Table 2,	40	„	4.31	
Table 3,	35	„	3.56	
„	30	„	2.85	
„	13	„	1.11	

From this it would appear that the *practical effective power,* derived from the Fan, up to a velocity of 60 rev. per min., is *greater* than that theoretically deduced.

It was found impossible to drive the Fan, with safety, at a greater speed than 60 rev. per min., in consequence of its imperfect construction; this, therefore, prevented the higher velocities, mentioned by Mr. Brunton, being experimented upon.

The practical results deducible from the above memoranda may be included in the following :—

1st.—That the rarefaction produced in the upcast shaft, increases in *greater proportion*, than a like increase in the speed, or number of revolutions made by the Fan per minute. Or, that when the *speed is doubled* (all other considerations being the same), the *rarefaction* is increased from 2 *to* 3 *times.*

2nd.—That the ratio existing between the *speed* of the Fan, and the *useful effect*, shewn in the quantity of air exhausted from the mine, varies considerably, and is, no doubt, governed principally by the conditions of the mine through which the air has to travel. An *approximate ratio*, is however shewn, and appears to be an increase of about 500 c. ft. of air, for every additional revolution of the Fan per minute.

With *good airways*, and a *low water gauge*, this Fan shews itself to be an efficient ventilating power, *even at low velocities ;* but with *contracted airways*, and a *high-water gauge*, a most *in*-efficient machine.

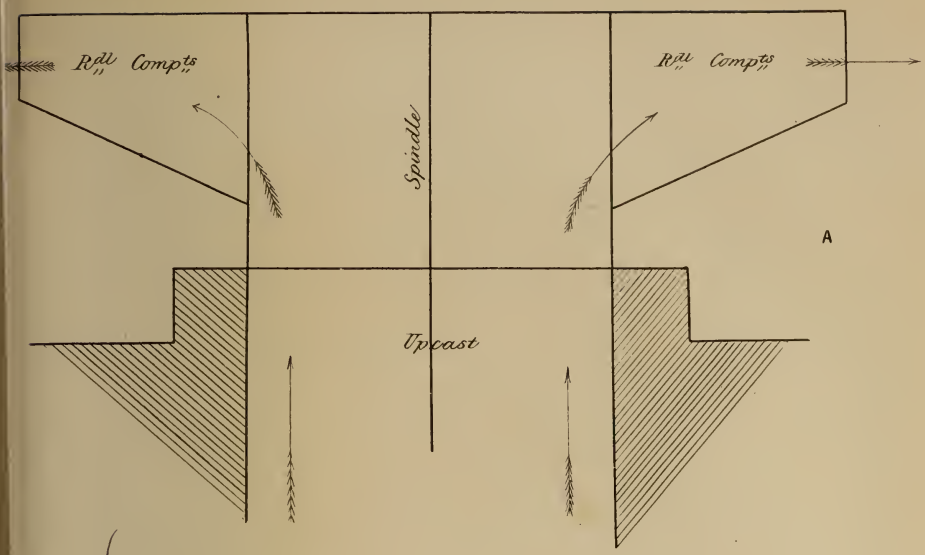
The well known law of ventilation expressed in the formula

$$P = L \times A^2$$

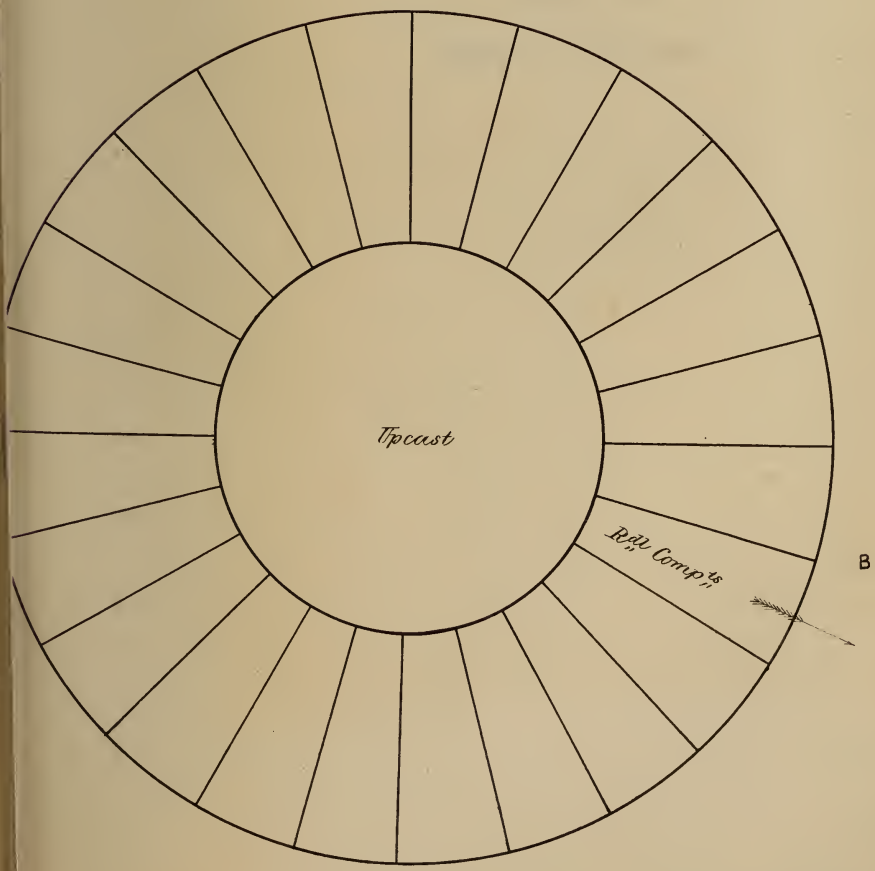
Where P ventilating power—L, the length of aircourse ; and A, velocity with which the air is made to travel, does not *clearly* appear in these experiments. This may possibly arise from the difficulty of correctly estimating the full power *derived* from the Fan.

Before concluding these memoranda, I cannot pass over a form of ventilating Fan introduced by Mr. J. Nasmyth, and now at work at the Abercarn Colliery, *identical in principle* with Brunton's. It is described by our worthy President, in a communication made by him to the Inst. M. E. Birmingham, in the following terms :—

"The Fan A. A. (Fig. 4), is 13½ ft. diameter, with 8 vanes, "each 3 ft. 6 in. long, and 3 ft. wide. It is fixed on a horizontal "shaft B, 8 ft. 7 inches in length from centre to centre of bearings, "which are 9 inches long by 4½ inches diameter. The vanes are



Figs 1.



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BRUNTON'S VENTILATING FAN.

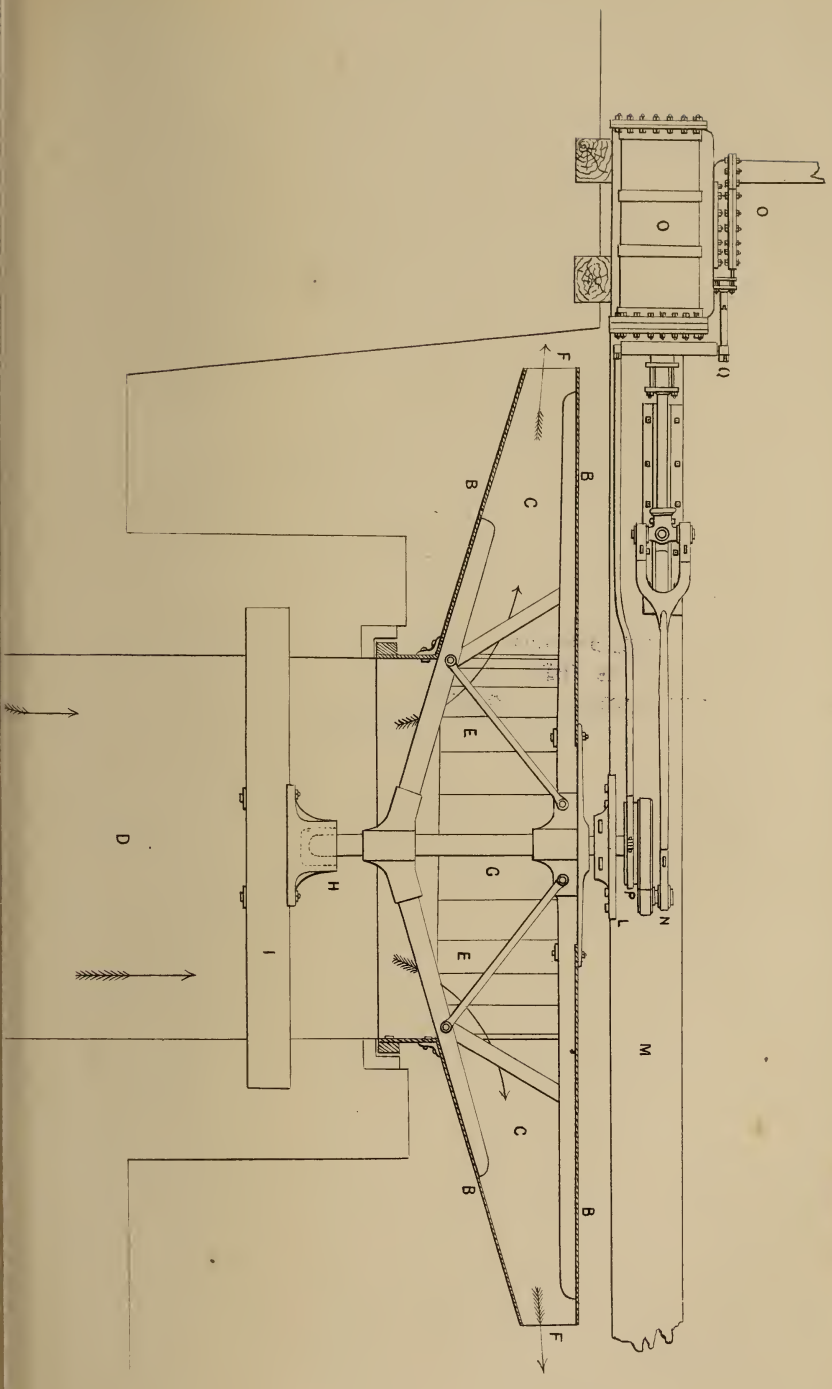

Fig. 2.

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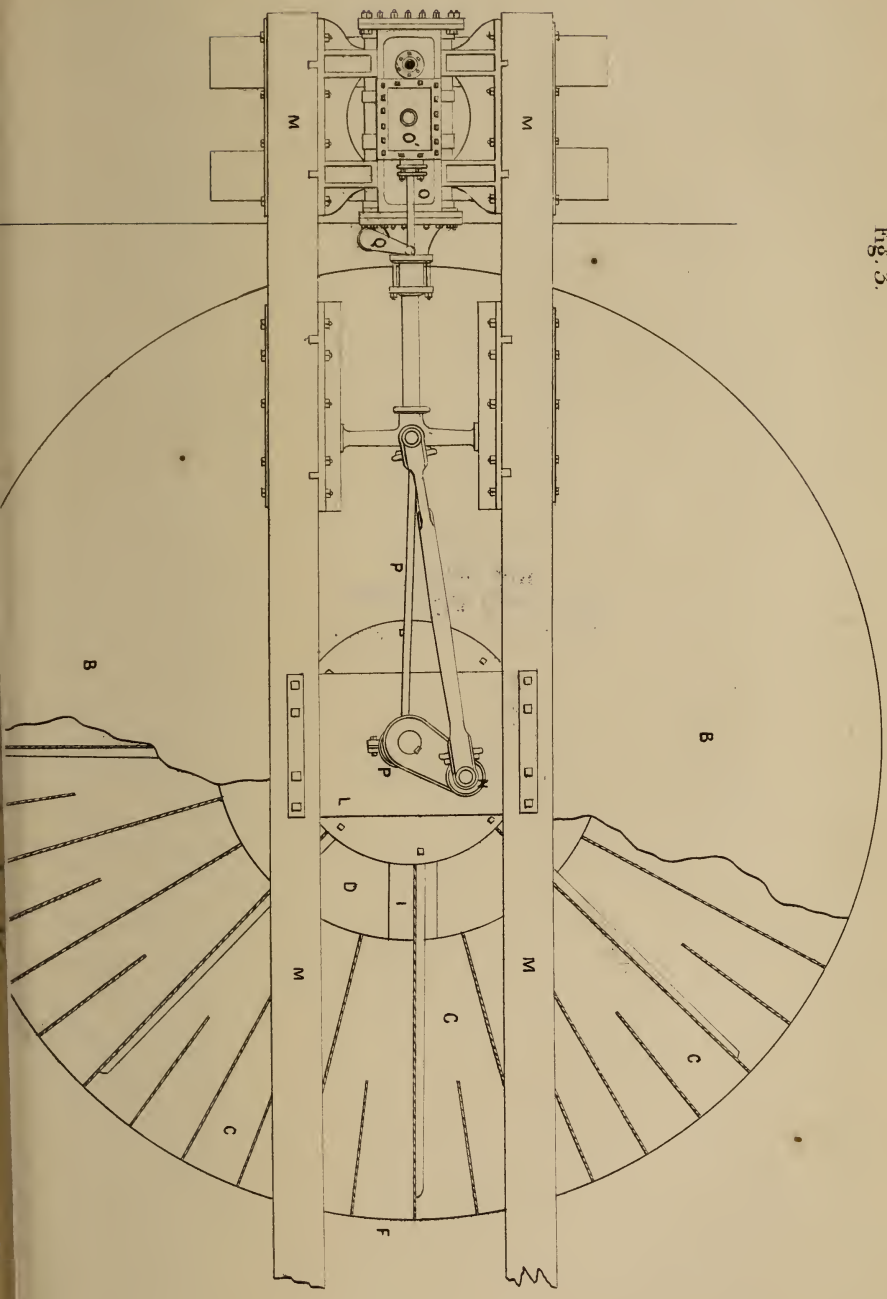

Fig. 3.

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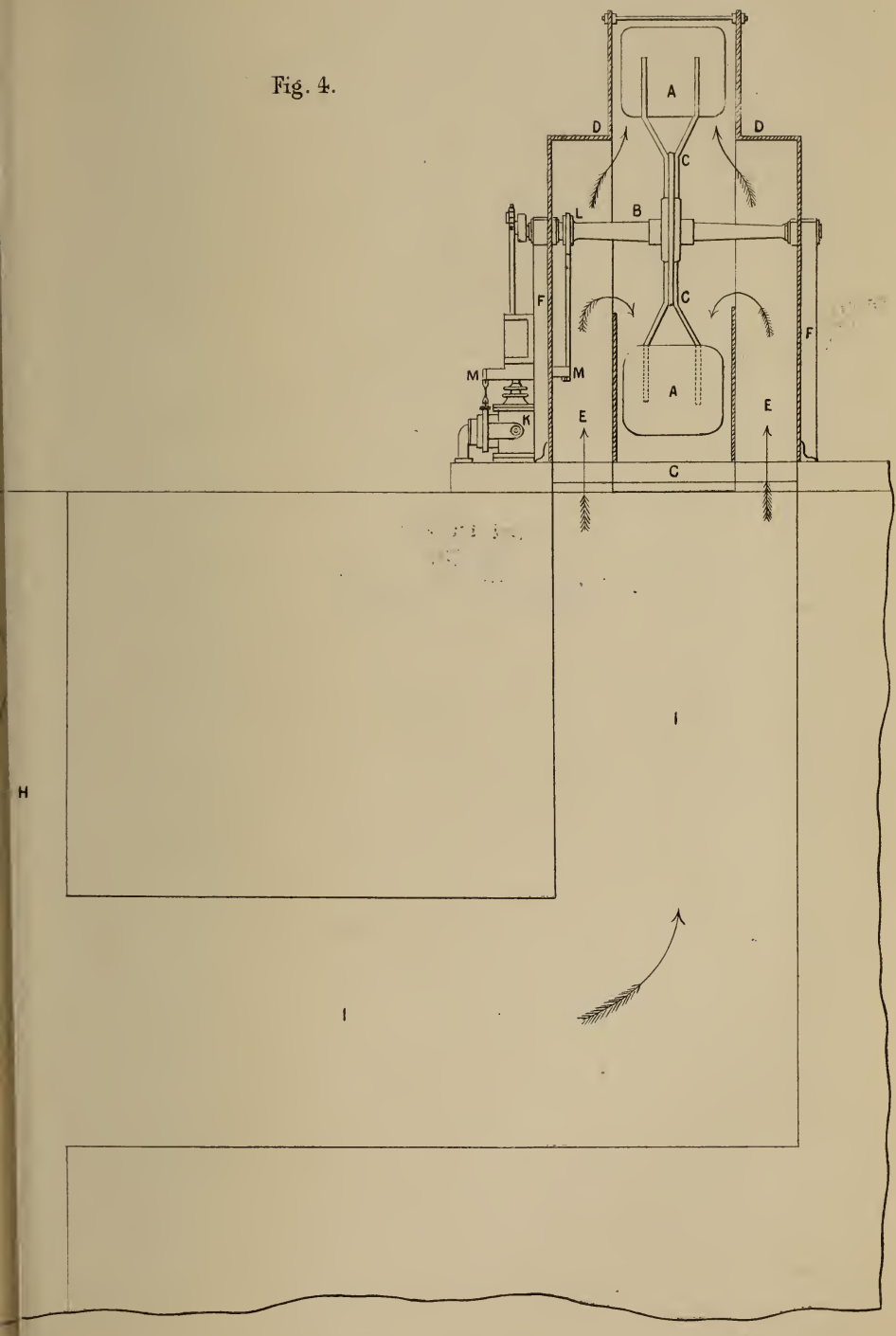
BRUNTON'S VENTILATING FAN.

Fig. 4.



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"of thin plate iron, and carried by forked wrought iron arms, se-
"cured to a centre disc C, fixed upon the shaft B. The Fan works
"within a casing D.D., consisting of two fixed sides of thin wrought
"plate, entirely open round the circumference, and connected to-
"gether by stay rods; the sides are 3 inches clear from the edges
"of the vanes, and have a circular opening 6 ft. diameter in the
"centre of each, from which rectangular wrought iron trunks E. E.
"are carried down for the entrance of the air, the bearings for the
"Fan shaft B being fixed in the outer side of these trunks, which
"are strengthened for the purpose by vertical cast-iron standards
"F bolted to them and resting upon the foundation G.

"The two air trunks E E join together below the Fan, and
"communicate with the pit H by means of a horizontal tunnel I,
"which enters the pit at 21 ft. from the top.

"The Fan is driven by a small direct-acting non-condensing
"engine K, which is fixed upon the face of one of the vertical cast-
"iron standards F, and is connected to a crank on the end of shaft
"B. The steam cylinder is 12 inches diameter and 12 inches
"stroke, and is worked by steam from the boilers of the winding
"engine of the pit, at a pressure of about 13 lbs. per sqr. inch. The
"eccentric L for the slide valve is placed just inside the air trunk
"E, and works the valve through a short weigh-shaft M, with a
"lever on the outside.

"The pit H is of an oval form, 10 ft. × 18 ft., and divided near
"the centre by a timber brattice, the one side forming the upcast
"shaft, and the other the downcast.

"The total depth of the pit is nearly 300 yards, and at a depth
"of 120 yards a split of air is taken off and coursed through work-
"ings, from which coal and fireclay are got; the larger portion of
"the air descends to the bottom of the pit, and is there split into
"many courses, to work two separate seams of coal and a vein of
"ironstone. The total length of road laid with plates or rails in the
"workings is about 7 miles, and the working faces amount to nearly
"double that distance. The longest distance that is traversed by
"any single course or split of air in passing from the downcast to

"the upcast shaft, is nearly 2 miles. The quantity of materials "raised from the pit is about 500 tons daily.

"The speed at which the ventilating Fan is usually worked is "about 60 revolutions per minute, giving a velocity at the circum- "ference of the Fan of 2,545 ft. per minute; 45,000 c. ft. of air per "minute are then drawn through the mine, nearly one-third of "which ventilates the upper workings, and the rest passes through "the lower workings.

"Table (A) appended, gives the results of a series of experiments "made with this ventilating Fan, under the direction of the author, "by Mr. R. S. Roper, shewing that the quantity of air delivered at "the velocities of 60 and 80 revolutions of the Fan per minute, is "45,000 and 56,000 c. ft. per minute, with a velocity of current of "782 and 1037 feet per minute respectively, or about 9 and 12 "miles per hour; and the degree of vacuum or exhaustion in the "upcast shaft is ·50 and ·90 of an inch of water respectively."

TABLE A.

Synopsis of Experiments on Fan Ventilation.—By Mr. Ebnz. Rogers, Mem. Inst. M.E., F.G.S., &c

	HEIGHT OF BAROMETER.		TEMPERATURE BY FAHRENHEITS THERMOMETER.				Revolutions of fan ℔ minute.	Waterguage.	Velocity of air in ft. ℔ minute.	Cubic feet of air ℔ minute.	Steam guage on fan.	Theoretical consumption of coal ℔ hour.
	At the surface.	At the bottom.	Top of downcast.	Bottom of downcast.	Bottom of Upcast.	10yds. from top of upcast.						
	Ins.	Ins.	Deg.	Deg.	Deg.	Deg.	No.	Ins.	Ln. Ft.	C. Ft.	Lbs.	Lbs.
Mean of 12 experiments, Natural Ventilation	29.61	30.60	41.10	51.73	55.56	48.00	...	.15	446.0	24,325	...	...
Mean of 4 experiments, Fan Ventilation	29.85	30.85	38.10	50.10	53.93	47.30	60	.50	781.8	45,187	13.0	17.4
Mean of 5 experiments, Fan Ventilation.....	29.65	30.61	41.40	50.70	55.10	48.70	80	.90	1037.0	56,555	19.3	23.2

Mr. Roger's experiments on this Fan, shew—

For 60 rev. per min., with ·50 waterguage
a quantity of..... 20,862
For 80 rev per min , with ·90 waterguage
a quantity of... 32,230

} c. ft of air exhausted by *Fan.*

Giving an increase of ·120 lbs. per square foot, in the rarefaction produced, and 568·4 cubic feet, in quantity of air exhausted from the Mine, for every additional revolution of the Fan over 60 revolutions per minute. And at

60 rev. p. min., a pressure per sq. ft. of 1·90 lbs.,=1·117 h. p. utilized
80 „ „ 4·50 lbs.,=4·660 do.

Equal to a loss of the power *applied*
at 60 rev. per min., of 58·17 per cent.
„ 80 „ 11·87 „

For easy reference and comparison, I have entered the results, of each Fan, in the following Table (5):—

Description of Fan, and No. of rev. per min.	Quantity of air exhausted by Fan per minute.	Per centage of loss of power applied.	Horse-power utilized.	Waterguage.	Additional rarefaction in lbs. pressure per sqr. ft., for every add. rev.	Add. quan. of air exhausted from mine for every add rev.	REMARKS.
Rev.	C. Ft.		H.P.	Ins.	Lbs	C. Ft.	
Nasmyth's Fan, Table A 60	20,862	58.17	1.117	.50	.120	568.4	
" " 80	32,230	11.87	4.660	.90			
Brunton's Fan, Table 1 60	20,100	77.40	5.369	1.38			
" " 55	17,850	81.10	4.122	1.20	.195	513.0	With the air coursing through the workings.
" " 50	14,920	84.27	3.129	1.01		129.0	
" Table 2 40	13,630	86.91	2.075	.73			
" Table 3 40	21,990	74.30	4.237	.64			
" " 35	20,950	83.65	2.269	.57	.085	580.0	
" " 30	16,190	86.35	1.624	.50			
" Table 1 60	30,650	66;32	8.00	1.38	.189	430.0	Main separation doors open, air not going through workings.
" " 40	22,000	79,03	3.320	.73			

Had the mechanical construction of Brunton's Fan been better arranged, so as to reduce the power, requisite to drive it at the various speeds, to a minimum, or at least to an equality with Nasmyth's Fan, this Table would have shewn results greatly in favour of Brunton's application.

I cannot but admit Mr. Nasmyth's very successful mechanical application of this principle; but, at the same time, I think that an improved Fan would be the result of amalgamating the two forms now noticed—that is, by lengthening the spindle of Brunton's Fan, placing it in a horizontal instead of a vertical position, and adding a reversed counterpart of the Fan in juxta-position on the same spindle; using, at the same time, a duplicate of Mr. Nasmyth's very complete and simple mechanical arrangement.

In the preceding remarks, I have confined myself entirely to the practical effects produced by this ventilator, as it has been my aim to present facts and memoranda on this mechanical appliance, to those members of our body who hold responsible situations as Colliery Managers, and who may, perhaps, be desirous of finding a substitute for the furnace, as a ventilating power, for fiery, though shallow mines, rather than theoretical expositions, better suited to the scientific reader than the practical worker. At the same time, I trust that the importance of the subject will induce its more scientific, and theoretical consideration, at some future time.

In the foregoing memoranda, I would be understood not to advocate the use of Brunton's Fan in preference to other, perhaps superior, but more complex, ventilators, such as Struve's, Fabry's, Lemeilles, &c., but simply to have endeavoured to arrange, and tabulate, such *facts* as come under my notice, with a view to the better understanding, and impartial enquiry, into the important subject of Mechanical Ventilation, as applied to *shallow*, but fiery mines.

DISCUSSION.

Mr. Clark would like to know the largest quantity of air obtained in any one experiment, and what it would have been with natural ventilation; together with the extent of workings through which the air circulated.

Mr. HUXHAM replied that the greatest quantity of air obtained in any one experiment was about 34,000 feet per minute, whereas natural ventilation would only have given about 3,900 feet. The length of workings was about 530 yards.

Mr. BEDLINGTON was at a loss to know what was gained by adopting machine ventilation over what could be obtained by the furnace. The quantity of air obtained by this machine was very small—some 20 to 30 thousand cubic feet per minute, and a six feet Flue would give as much. He had under his control flues that produced 45 to 50 thousand cubic feet. If it were said that mechanical ventilation was safer for fiery collieries, he would reply that Dumb Drifts gave the same safety without impairing the ventilation produced by the furnace. We all could get more than 30 thousand feet per minute without adopting machinery, which was liable to get out of repair.

Mr. CLARK thought Mr. Bedlington was somewhat in error as to the application of the machine ventilator. It was not intended to supersede the ordinary furnace, but to apply it to new winnings where gas was found in a high state of tension, and where the workings were of small extent. In such cases the fan could be used with perfect safety, when the furnace could not be used.

Mr. DICKINSON said that whatever the relative merits of different modes of ventilating might be, the depth of a pit must always form an important element in the calculation. The deeper the pit, the more favourable for the furnace; and the shallower the pit, the more unfavourable for the furnace. We were many of us too apt to underrate an invention of this kind. We disliked change, nor did we like to discharge an old servant. In opening out fiery mines, it was not safe to put in furnaces; and he thought any good mechanical apparatus ought not to be undervalued.

Mr. DAVID LLEWELLYN enquired if the steam jet could not be as well applied; it could be attached to the engine-boilers.

The PRESIDENT said the steam jet had been found to be too expensive.

Mr. DICKINSON had no doubt it was a very useful assistant to other ventilating powers.

Mr. BASSETT would like to know whether a separate engine was required to drive the ventilator, and if so, what its power should be, and the cost of it.

Mr. HUXHAM merely gave results, and believed he was right in stating that machine ventilation was cheaper than furnace ventilation in shallow mines No doubt, in deep mines, furnace ventilation was cheapest. As regarded the questions put by Mr. Bassett, the cost of the whole machine, including the engine, was, as far as he could recollect, £150 to £200; and from £15 to £20 per annum would keep it going and pay for the necessary repairs. He did not believe that any furnace in South Wales could be kept going for the money.

The cost of working the ventilator at Abercarn was, he believed, about one-tenth of that of a furnace of the same power.

The PRESIDENT said that the experiment at Abercarn, in the application of mechanical power to colliery ventilation, had been carried out jointly by Mr. James Nasmyth and himself, but to Mr. Nasmyth belonged the most of the merit whatever was due. The cost of coal is not more than one-tenth of that used by the furnace to produce an equal amount of ventilation; and this had been proved not only by himself at Abercarn, but also by Mr. Nasmyth, at the collieries of Earl Fitzwilliam, where a larger fan was now at work. At the discussion of this subject before the Institution of Mechanical Engineers at Birmingham, there seemed no doubt upon the minds of the members present that mechanical ventilation would ultimately supersede furnaces. Only a few days ago, a fearful accident had occurred in Durham, consequent upon a brattice taking fire. That could not have happened if there had been a mechanical ventilator. He had no doubt that we should soon have the mechanical superseding the old plan; and he had it upon good authority, that they were now at Abercarn passing 60,000 feet of air per minute, with the power, if they chose, to raise the quantity to 120,000 feet. The Abercarn had been four or five years in use, and had not cost ten shillings in repairs yet; nor did it require a separate attendant.

Mr. DICKINSON said that the accident alluded to by the President ought to be the death-blow to all bratticed shafts.

Mr. BEDLINGTON: Especially wooden ones.

A vote of thanks to Mr. Huxham for his valuable paper was carried unanimously.

The SECRETARY then read the following paper:—

ON HENRY CORT'S INVENTION OF THE PUDDLING FURNACE, AND THE GROOVED ROLLERS, IN THE MANUFACTURE OF IRON.

By Mr. THOMAS WEBSTER.

To record the steps by which the manufacture of British Iron attained its present state, and to assign to those who laboured most successfully in its advancement, and contributed important steps in its progress, would appear a fitting subject with which to occupy the attention of a scientific meeting assembled in this great seat of its manufacture.

Notwithstanding all that has been written, it has appeared to me the true merits of Henry Cort have not received that meed of public approbation and reward to which they are justly entitled, a result to which many causes may have contributed, but which the posterity of those who might have been swayed by rival or conflicting interests is never slow to acknowledge.

The substitution of pit, or sea coal, for wood in combination with cold blast, and of the anthracite, or stone coal, in combination with the hot blast, are steps or stages constituting epochs in the history of the manufacture which have attracted a large share of public attention; they presented simple and leading features such as the least initiated can appreciate. The names of Simon Sturtevant and Lord Dudley, in the 17th century, and of Crane and Neilson of our own times, will stand conspicuous in the history of the pioneers of progress in this department of British industry. The name of Cort has not acquired the position to which it appears entitled.

The grant of a patent for 31 years, by King James, in 1612, to Simon Sturtevant, (whose labours in connection with the translation of the Bible are matters of history), for the manufacture of iron with pit coal, in all its branches, consisted of publishing an account of his discoveries, and soon after he was compelled to leave the kingdom.

A grant to John Stevenson, in the following year, for the same object, upon the same conditions: similar grants to others equally unsuccessful imitators, followed by similar fate, were the natural consequence of the researches after a new fuel, upon the gradual exhaustion of the supply of wood in the localities of England in which the iron manufactures were then chiefly carried on.

The Lord Dudley, who obtained a grant of letters patent in 1621 from King James, would appear to be the first successful inventor, and to have succeeded in making as much as three tons of forged bar iron weekly, which is perhaps the best evidence of his success; but he encountered the opposition of rival manufacturers, and, though his patent was saved by express reservation in the famous statute of monopolies, 21 James I., c. 3, its term was limited to 14 years. The preservation of this patent, and the granting of others for a similar object, in some of which a rent or share of the profits was reserved to the King, shows the importance which then attached to the new manufacture.

In the interval of another century were produced many grants for the same object; and, in 1728, a grant was made to Mr. Wood for making raw iron or iron metal, in an air furnace, with pit coal, whereby, as is stated in the grant, the nation may be supplied with all the iron it requires, and prevent the bringing of iron from foreign parts, which amounts to about 20,000 tons annually.

No reliable information exists as to the quantity made in England, but Sturtevant states, in his Metallica, that, in the 12th year of James, in England, Scotland, Ireland, and Wales, 800 furnaces, forges, and iron mills were making iron with charcoal, and, assuming 300 to be blast furnaces, making 15 tons of pig iron weekly,

and to blow only 40 weeks annually, the whole quantity made would be 180,000 tons.

Invention, up to this time, appears to have had reference to the reducing of iron from the ore: but in the first half of the 18th century various patents were granted for improvements in the manufacture of iron, certain ingredients being put into fusion, or melted with pig, sow, or other brittle iron; the adoption of fluxes, such as slag, cinder, lime, kelp, soap wash, and other substances.

Attention was also directed to the use of caverns, as a substitute for the hollow fire and blast; and, in 1762, a patent was granted to John Roebuck for "a way of making malleable iron from cast iron, by melting it on a hearth with a blast, and working it until it is reduced to nature, after which it is reheated and drawn out under a forge hammer into bar iron;" and, in 1766, a patent was granted to J. and G. Cranage (then employed by the Coalbrook Dale Company, in Shropshire,) for making pig iron malleable, in a reverberatory furnace, with raw pit coal, termed the burring process; also, in 1783, a patent was granted to Peter Onions, for making or refining cast or pig iron, and converting the same from a fluid state into wrought iron.

The whole of these patents, from 1762, like all the rest previously granted, were total failures, as proved by the fact, that, instead of 300 blast furnaces, in Dudley's time, making, in one year, 180,000 tons of pig iron, the whole having dwindled down to 59 furnaces, producing only 17,350 tons with charcoal fuel, in 1740, while the whole make of pig iron, with charcoal fuel, had not increased a single ton in 1782, being of inferior quality, and used only for common purposes, but not employed in the navy or other works, where attention was paid to the quality of the material; and soon after this period, in 1784, Sweden and Russia supplied to this country 75,000 tons of charcoal bar iron.

In 1783 and 1784, Henry Cort, an iron manufacturer at Fontley, near Gosport, in Hampshire, obtained two letters patent for inventions which revolutionised the iron trade, and became the

foundation of the present British Iron Manufacture. He had conceived an idea of rendering his native country independent of foreign countries for the supply of iron, and the result of his labours show how well he had anticipated the means for the accomplishment of this great object, against the adverse predictions of some of the highest authorities in the British Iron Trade, and that discouragement and discountenance which is too often the inheritance of the successful inventor.

The processes described in the specifications of Henry Cort are adopted, almost without variation, to the present day, most of what has been done being in the way of addition to and perfecting the furnaces, which, in all their essential features, still remain as described and used by Cort.

In the manufacture of malleable iron, the processes termed puddling, balling, piling, and fagotting, as is well known, are of universal adoption. It will be interesting to see how these are disclosed and described in the specifications of the above patents.

The specification of the first patent, dated 16th May, 1783, for "his peculiar method and process of preparing, welding, and working various sorts of iron, and of reducing the same into uses by machinery, a furnace, and other apparatus, adapted and applied to the same purposes," describes making a faggot of bars to be welded by means of grooved rollers, after being heated in a balling or reverberatory furnace, instead of in a fire blown by a blast. By passing this faggot of iron through rollers, at a welding heat, "all the earthy particles are pressed out, and the iron is compressed into a fibrous tough state. A bar of the most ordinary iron being passed through becomes instantly of good quality, and two or more such bars, or any pieces of impure iron, heated in the same manner, and passed through the rollers together, become at once welded into one solid body, and matured into good tough iron, without being cleansed in the scouring barrel or otherwise."

Not a single word of explanation is necessary to render Cort's description of the grooved rollers more clear than it already is, and

it may be observed that this description is perfectly applicable to the rollers now employed by iron manufacturers. Indeed, Mr. Cort's own language might be applied without the smallest alteration, as the letter-press description of the engraving of the rolls now used, after 74 years have passed, at two of the largest works in the kingdom, Cyfarthfa and Dowlais, as given in the "Treatise on the Iron Manufacture of Great Britain," by Mr. William Truran, Engineer.

The diamond, the gothic, and other forms of grooves given to the rollers for specific purposes, are manifestly the same in principle as the grooves and collars in Cort's Rollers, inasmuch as they all present a given sectional space, through which the iron, under operation, is compelled to pass, being unable to escape either upwards or downwards, or on either side.

The specification of the patent, dated 12th of June, 1784, for "obtaining iron of purer quality, in larger quantities, by a more effectual application of fires and machinery, and with greater yield than by previous processes," describes a reverberatory furnace, heated by coal, with a concave bottom, into which the fluid metal is run from the furnace, or pig iron is put in and melted. The specification having described the melting of the iron, and the working and stirring up with iron bars of the melted mass of the iron, until the metal loses its fusibility, and is brought to nature, so as to be prepared for stamping, piling, or working in an air furnace, with pots or without, proceeds to describe the reheating of the loops and drawing them down under the hammer, or by grooved rollers at a welding heat, and concludes by stating, that the iron and steel so prepared is of good quality, whether the blistered steel be made from fagotted iron or from iron made from the above process; and that the whole method is completed without using finery, charcoal, coke, chaffery, or hollow fire, and without requiring blast or the use of fluxes.

The two specifications of Henry Cort describe substantially the leading features of the manufacture of British iron as at present practised; but it must always be borne in mind, that he who first

put in practice and demonstrated the utility of his invention in such manner as to impress a change in the courses of the manufacture at the time, or immediately in connection with the grant of his patent, is the Inventor, and benefactor of the public.

Here then, in Henry Cort's discoveries, is precisely that combination of the two inventions—puddling, balling, piling, and fagotting through grooved rollers, which has formed the one sole basis for that enormous extension of the iron manufacture of Great Britain, which has contributed so largely, for more than half a century, to the wealth, power, and independence of the British Nation.

Researches into the records of abortive experiments, of suggestions contained in the specifications of patents not carried out, of so called inventions, of which the Rolls of the Court of Chancery furnish the only evidence, show how little was the step, how small was the amount of actual discovery, on the part of many who have changed the whole face of a manufacture. To argue as to, or to estimate, the merit of an invention upon such data, is most fallacious. The history of progress, in every department of knowledge, whether of natural or applied sciences, or commercial, political, or social economy, shows the real merit to consist in combining and adopting what was before known, in adding the last or some connecting link in the chain of discovery, or in the sequence of events by that patient perseverance, without which no invention or discovery can bear fruit, or attain practical success.

Cort, like most other pioneers in a great alteration, has had his detractors: those who represented how much of his processes were know before—how little he had added to the previous stock of knowledge—how much of the present practice is due to further and other improvements. Thus metal rollers, with "notches or furrows on their surfaces," many have known; as suggested by Payne, in 1728, for reducing, to a state of malleability, iron heated by various substances, which would make the like change as charcoal. But the interval of more than half a century, which elapsed, saw no

practical result of such a suggestion, no trace or connection of a permanent change in the course of manufacture from or with such suggestion. The most eminent manufacturers of the day made no alteration in their previous proceeding, and, up to 1787, the late Mr. Richard Crawshay went on forging his ten tons of iron per week in the Welsh districts.

It is perfectly true that iron bottoms have been substituted for sand, and that by extending the length of the furnace, a second charge of cast iron may be introduced and partially heated, during the finishing operations on the first, so as to economise time and labour. This is but an expansion and extension of the original invention, and furnishes the best evidence of the soundness of the principles upon which it rested; but Cort's description of his process, as published to the world in 1783 and 1784, and as conducted by him at his works, at Fontley, applies to the processes as practised at the present day. All that has been done during the last 75 years, has been in the way of such addition to Cort's processes, and of such improvement in his furnaces as experience and manipulation has, from time to time, suggested. Bessemer has not yet dispensed with Cort's puddling furnace, or any other enterprising man found a suitable substitute for the heating in a reverberatory furnace, or the balling, piling, or faggotting, or the working or welding by grooved rollers.

To estimate the importance of an invention, the merit due to its author, and introduce the acts done at the time, and the conduct of those parties engaged in the particular manufacture in this unexampled case, the testimony from these sources, to the merit of Cort, is most conclusive. A contemporary of Cort, one of the most enlightened and experienced persons, an iron manufacturer for 20 years previous to 1783, Mr. Alexander Rabey, having, in the first instance, regarded with distrust and disbelief the attempt to render Great Britain independent of foreign iron, afterwards avowed his conviction of the full and complete success of the new processes. But the inventions were subjected to most severe and satisfactory tests in the year 1785. Forty-eight trials of the iron produced by

Cort's process, from common ship ballast, the worst quality of cast iron, were made in six of the Royal Dock Yards, superintended by the celebrated Professor of Chemistry, Dr. Joseph Black, of Edinburgh, and conducted by the Master Smith of each Dock Yard, for the information of the Government. The result of these trials, made against Swedish iron, of the best marks, was as under:—

In 5 out of 6 trials, for the largest Anchors, Cort's Iron proved superior.

10	"	28	"	for Hoops and Iron Bound Blocks, Cort's Iron proved stronger.
15	"		"	Equal.
3	"		"	Weaker.
3	"	14	"	for Bolts in Driving and Holding Fast, Cort's Iron proved stronger.
7	"		"	Equal
4	"		"	Weaker.

From this time the Navy Board contracted for and received all the iron that Cort made at Fontley, and announced in their advertisements for tenders, that no iron would be accepted without a certificate that it was made by Cort's process; and from this date the import of foreign iron fell off, and decreased from 75,000 tons per annum to about one-third of that amount, to be employed almost exclusively in the choicest description of steel, while the steel for two-thirds of the cutley trade, in Sheffield, is now made from rolled iron. The workmen of the dock yards feeling strongly, as Englishmen, that their native country was no longer dependent on foreign iron for naval implements, carried in triumphial procession the man, whose genius and perseverance had shown the way to make England her own purveyor in a material of such national importance.

In 1787, after this demonstration of the complete success of Cort's inventions, Messrs. Jenkins & Co., of Rogerstone, near Newport, were the first to erect rolling mills for making bar iron for tin plates, under the direction of Mr. Cort's workmen, and of Mr. Brown, the ancester of Mr. Thos. Brown, the managing partner of

the Ebbw Vale Company; and in the same year, the late Mr. Richard Crawshay, at that time, forging only ten tons of iron weekly, visited Cort's Works, at Fontley, with his partner, Mr. James Corkshutt, who had been engaged in the iron trade for twenty years previously, when they arranged with Cort for the erection of all his patent works at Cyfarthfa.

The works being nearly completed, the drawings were borrowed by the late Mr. Samuel Homfray, and these two eminent ironmasters entered into, and signed contracts to pay Mr. Cort ten shillings per ton for all iron made under his patents as the license dues; and other Iron Companies entered into and signed contracts, whereby more than £180,000 would have been payable to the patentee, when the patents expired in 1798. Among the many who appreciated highly the merits of Cort, and who did not hesitate to acknowledge his services, the late Lord Sheffield, in 1786, in his "Observations on the Commerce of the American States," remarks "If Mr. Cort's very ingenious and meritorious improvements in the art of making and working iron, the steam-engine of Boulton and Watt, and Lord Dundonald's discovery of making coke at half the present price, should all succeed, it is not asserting too much to say, that event would be more advantageous to Great Britain than thirteen colonies; it would give the complete command of the iron trade to this country, with all its vast advantages to navigation;" and the late Mr. Richard Crawshay, in a letter dated Cyfarthfa Iron Works, Dec. 14th, 1808, addressed to the late Lord Sheffield's Secretary, after fully describing the new method of making iron, observes—"I took it from a Mr. Cort, who had a little mill at Fontley, in Hampshire;" and concludes by saying, "I have thus acquainted you with my method, from which I am now making above 10,000 tons a year at this place."

The merit of Henry Cort, as the author and first introducer of the several processes already referred to, in the manufacture of iron, whereby the cost has been reduced more than two-thirds on an average of the last 70 years, is indisputable.

The pecuinary benefit to the nation has been estimated by

the writer of an article, on iron, in the 8th edition, 12 volume, of the Encyclopædia Brittanica, as stated in a memorial presented by the Right Honourable Lord Stanley, M.P., last year, to Viscount Palmerston, and signed by 25 of the most eminent authorities, including Mr. Anthony Hill, of the Plymouth Works, and other iron manufacturers, at no less a sum than £600,000,000 sterling.

It would be foreign to the present occasion to dwell on the circumstances which not only prevented Mr. Cort from receiving any portion of the just remuneration, under his patent already referred to, for his skill and industry, but also involved him in other losses, making altogether £250,000, as stated in the memorial beforementioned. They present a most lamentable chapter in the history of inventors; too many of whom, from causes wholly beyond their control, live on without participation in the wealth which they have created for the nation.

A vote of thanks to Mr. Webster, for his valuable Paper, was carried unanimously.

The Secretary then read the following Paper:—

THE COMPARITIVE VALUE OF THE FUELS.

By Mr. MARK FRYAR, Bristol.

In no case will the results of accurate experiments be directly contradictory to the results of the operations of physical laws. Very much has been done for man in the great laboratory of nature; elementary matter has been combined, so as to form a vast number of different substances—presenting an almost endless variety of external appearances, and most of them exhibiting widely different properties. The gathering together of those substances into subterraneous masses, lodes and seams, has, in many cases, evidently resulted from that very peculiar property in single bodies, called chemical affinity; so that in remembering the components which may form any substance brought under consideration, and the law by which they have been combined, we have before us the very agent, to whose work we are indebted, either for gathering together the minerals so as to facilitate their extraction, or for producing the material, the profitable use of which depends upon the presence of each component. The fuels are those substances, in nature, which have been produced by the combination of carbon, oxygen, and hydrogen; and their relative value very much depends upon the proportions in which the carbon and hydrogen enter into their composition, whilst their entire consumption depends upon the presence of oxygen, either as a natural component, or as supplied by the atmosphere. Whatever may be said by experimenters, respecting the results of their experiments with fuels, a common sense investigation of the subject, aided by a fair amount of scientific knowledge,

will show, that unless these substances are naturally combined in the fuel, or can be brought together with ease and without expense, it must be comparatively valueless.

The coals proper, or what are generally called pit coals, are now in most extensive use as fuel; and of these, it is well known that the varieties which will produce the largest amount of heat, in the shortest space of time, are the most valuable as a steam coal—considered, simply, with respect to their heating properties. But these properties are not the only ones which ought to guide the engineer, in his selection of coals for steam navigation, or for locomotive engines. Their difference of specific gravity, and which is in a great measure a consequence of this, the difference in the amount of stowage they respectively require for equal weights, are points of great importance, and may constitute a coal most valuable for the above uses, whilst the heating property is a little below par, compared with coal of the highest calorific value. It is well known that there are several varieties of fuel, upon the peculiar properties of which very much commercial and national interest is now depending, and of these the pit coals are the majority. Coals, free from sulphur, somewhat porous, or which will readily break up on exposure to heat, and probably which contain a large amount of carbon, are required for smelting iron and other metals, whilst coals of the highest economic value, are the touchstone of success to railway and steam navigation companies, and their use by the government, a means of considerable decrease in expenditure from the purse of the nation. The substances principally used as fuel, are wood, peat, legnite, coal, and coke; and in this paper we shall endeavour to consider these separately and comparatively, without prejudice, and without restraint, from party or provincial influence.

The process of burning is purely chemical, and the facility with which fuel ignites and burns, depends, in a great measure, upon its chemical composition, and its porous texture. The rapidity with which it ignites, and the amount of flame it produces, is intimately connected with the amount of hydrogen it contains. The carburetts

of hydrogen, one containing equal volumes of carbon and hydrogen, and the other one of the former to two of the latter, are liberated from fuel by a heat below redness; and when the temperature is sufficiently high, the oxygen, from the fuel itself, or from the atmosphere, combines with each of these gases, causing flame, and producing carbonic acid and steam. Where there is a deficiency of oxygen, carbonic oxide, and free carbon, will also result from the combustion of the fuel, and unless these meet with a sufficient supply of oxygen, whilst their temperature are sufficiently high for combination, they will pass off in connection with the carbonic acid and steam, and very much diminish the calorific value of the fuel. Fuel, containing little or no hydrogen, will only produce flame when an insufficient quantity of oxygen is directly supplied to it for the production of carbonic acid; carbonic oxide is then the chief product which, on meeting with an additional supply of oxygen from the atmosphere, and whilst at a sufficiently high temperature, will ignite, and produce a beautiful blue flame, and carbonic acid. Carbonic acid gas, free nitrogen, and steam, pass off as useless products of the process of combustion, and where sulphur is in the fuel, a little sulphurous acid will be found to accompany them.

Wood.—Many important and useful lessons are to be derived, from an intelligent consideration of natural progress in sciences and arts, as intimately related to the developement of mineral wealth, and to the advancement of manufacturing engineering. Before the days of coal! and where, and what were the manufactures of this country? Then, they were found in the south and east parts, where forest wood abounded, which was the first kind of fuel man applied to serve some of his greatest purposes. Then, they were but the birth of a power struggling for developement; it was with them, then, the day of small things. Now! what would a Great Britain of forest wood do for their requirements? The coal fields are the parents of manufactures; the place of the coal has also become the place of the blast furnace, and of the mill, and with the increase of quantity of fuel from coal beds, over that from forests, we have increase of quality. This might have been anticipated by the man of seven centuries ago, could he have seen forward to the

nineteenth century, and had he acquainted himself with the ways in which a beneficient Providence rules for the general benefit of his creatures.

The lowest calorific effect obtained from wood, as given by Count Rumford, is from the thick shavings of oak, and is expressed by one pound of this fuel raising 24·748 lbs. of water, from 32° to 212 Fah; whilst the lowest of the series of bituminous coals, is from a continental mine, and is expressed by 1 lb of the fuel raising 43.9lbs. of water, from 32° to 212° F. The highest calorific effect from wood is, when limetree-wood, strongly dried, is the fuel, 1 lb raised 40.131lbs. of water, as before, whilst the highest effect from coal is, when the Aberdare Co.'s, Merthyr is the fuel, 1 lb raising 77·11lbs. of water, from 32° to 212°.

Now, the manufactures and steam engine appliances of this country are—

> "The wide world's wonder,
> And pride of Britain's sons."

And this a consequence of the discovery of extensive beds of coal and its superior economic value over the fuel from the forest.

The great drawback on the use of wood as fuel, is the amount of water it contains; some varieties, such as horse-chesnut, and white-fur, according to the experiments of Schübler, and Neuffer, being found to contain from 40 to 50 per cent., when felled, and after exposure to the air for 10 or 12 months, are still found to retain from 20 to 25 per cent.

The fuels, when burnt, all leave an incombustible residuum or ash. In wood, the amount of this varies, with the different kinds of trees and plants, and, probably, in a great measure, depends upon the soils in which they grow.

Peat.—The fuel, bearing this name, is one of no mean importance in extent and utility. The great marsh of Montoire, in France, near the mouth of the Loire, is said to be 150 miles in circumference. In Holland and North Germany, entire districts are covered by peat formations, from which large quantities of fuel are

annually furnished to the various manufactories in their vicinity; and in Ireland we have nearly 3,000,000 acres of peat-moor, being about one-seventh of the whole Island. Strange theories, it appears, once obtained amongst scientific men respecting the way in which these masses of vegetable matter of such vast extent, and from 2 or 3 to 30 feet in thickness, had been formed. One supposed them to be the wreck of once floating islands; another, that they were bituminous deposits from the sea; and a third, that they were now as they had grown, and were, consequently, to be looked upon as gigantic plants in actual state of growth. These theories have long since been exploded, and the peat formations are now found to be a variety of marsh plants; such as sedges, reeds, rushes, mosses, amongst which the moss, *sphagnum palustre*, chiefly predominates; these have grown in stagnant water, in a moist atmosphere, and where evaporation has gone on slowly. With change of season came their death, and out of their remains a second generation of plant life arose, which, in turn, became the soil of a third, and so on. The remains of plants very rapidly decay, when immersed in water, they lose their original solidity, and evolve carburetted hydrogen, carbonic acid, and where sulphates are decomposed, a little sulphuretted hydrogen. These large fields of vegetable debris may be considered, generally, as consisting of primary and recent formations. In the latter, the structure of the roots and stems of vegetables is still perfect; it is of very porous and light texture, and exceedingly soft and fragile; whilst in the former, all organic structure has disappeared, and the texture become earthy and compact.

At Cappoge, in Ireland, a process has been introduced whereby the peat is very highly compressed, by a powerful hydraulic press. On leaving the press it occupies about one-third of its previous volume, whilst it is found to have lost about two-fifths of its weight from the quantity of water expelled, and it is said to have no tendency to reabsorb water. The peat thus prepared can be delivered at 5s. per ton.* The great objection to this kind of fuel is the high per centage of ash it contains, being sometimes so abundant as to render

* Knapp's Technology.

it quite useless. Some of the Irish peats which have been analysed seem to be tolerably pure. In twenty-seven varieties from the Bog of Allen, the mean per centage of ash was not more than about 3.7, but in a variety from the neighbourhood of Tuam, in the West of Ireland, a mean of 37 per cent. was observed. The great difference in the composition of the ash in different varieties of peat, is owing to the geological character of the locality where they have been formed: when in limestone districts the principal component is carbonate of lime, and when amongst hills of igneous origin, silicious sand predominates. Peat also varies exceedingly in density—the heaviest varieties weighing as much as 1,100 lbs. per cubic yard, whilst the lightest does not exceed 500 lbs.

Compared with coal, as employed in furnaces, it is only about half as dense. The best varieties of prepared fuel from peat, bear a very favourable comparison with dried wood, being found to contain about 10 per cent. more carbon, and 2 per cent. hydrogen, and about 12 per cent. less water.

Lignite.—I am afraid I shall be considered a little wanting in scientific exactness, and not quite in conformity with what is, no doubt, a very correct and safe definition of coal, in not considering the lignites as a variety of coal, and speaking of them under that head. Coal is said to be any compressed mineralised vegetable substance which can be used for the purpose of fuel, and such lignite unquestionably is, only as there is such a marked difference between the lignites and what is called mineral or pit coal, with respect not only to their external appearance and structure, but also to their geological age, it will perhaps be better to consider them under a separate head. The lignites most probably all belong to the tertiary geological formation, whilst the mineral or pit coal is almost entirely confined to the primary. Considerable deposits of lignite are worked in Germany, and at Bovey Tracey, in Devonshire At Meiszner, in Germany, a bed of lignite is covered by a stratum of basalt, about 300 feet in thickness, and at Bovey Tracey there is a series of beds alternating with clay and sand, the whole resting upon the green sand of the chalk formation. The lowest bed of lignite, at

Bovey, is 17 feet in thickness, from which about 15,000 tons are extracted annually. This is consumed principally by the potteries in the neighbourhood, where they mix eight tons of it with one ton of good coal.

The original fibrous structure and general vegetable character of the lignites, is so well preserved, even the more tender parts, as leaves and fruit being so little altered, that a botanical diagnoses of the antediluvan plants has been undertaken with success. They give off a very unpleasant odour when burning, and on this account are not used as house fuel except by the poor people in the vicinity of the mines. The per centage of ash in them varies from 1 to 50, but is seldom found below 5 or above 10; and the per centage of water, even after exposure to summer air for some time, is as much as 20. Owing to the impurities contained in the ash, and the amount of heat which its water absorbs, it has not been much used for metallurgical purposes.

The mean of several analyses of lignite, by Regnault, after deducting the ash, and supposing the whole of the oxygen, combined with hydrogen to form water, would be nearly as follows:—

	Carbon.	Hydrogen.	Water.
Lignite or fibrous brown coal.....	63	1	36
Perfect lignite or earthy brown coal	72	2	26
Lignite passing into bitumen or pitch coal...	77	5.5	17.5

The specific gravity of the lignites examined by the officers of the Admiralty Coal Investigation, varied from 1·291 to 1·321, and is, therefore, about the same as that of ordinary pit coal. I have recently had my attention directed to a consideration of the lignites of Bovey Tracey, with a view to their use in some of the operations of metallurgy, but I am afraid that their obstinate absorption and retention of hygroscopic water, and the accidental impurities associated with them, will be very formidable difficulties in the way of their profitable appropriation to such purposes.

Coal.—The very wonderful and valuable series of carbonaceous beds, the normal geological position of which is near the top of

the primary or newer palæozoic formation, and from which we annually extract between 60 and 70 millions tons of fuel, are what we, inhabitants of Great Britain, are most largely interested in, and it is to the comparative economic value of the varieties of this kind of fuel that we wish specially to direct attention. We shall be able to treat the subject with greater clearness, and with better arrangement, by considering the coals under the following divisions, namely, highly bituminous, semi-bituminous, and anthracite. It must be remembered that those divisions of coal are by no means well defined, but that the varieties merge into each other by insensible gradations, and, moreover, that there are distinctive physical features and properties of coals apparently of the same age and in the same locality, which are not at all indicated by those divisions, such as the amount of sulphur they contain, their per centage of incombustible residuum when burning, and their practical and specific gravity affecting the space occupied by equal weights of the respective kinds. The coals worked in the Northern Districts, as in Scotland, in the counties of Northumberland and Durham, and in some parts of Lancashire, Yorkshire, and Derbyshire, are principally of the highly bituminous variety. This property appears to be intimately connected with the relative quantities of oxygen and hydrogen contained in the coals, and to the proportion which these gases bear to the amount of carbon. The average of the analysis of ten specimens of the Newcastle Coal, as given in the third official report to Government on the coals suited to the steam navy, shows 82·85 carbon, 5·32 hydrogen, and 5·77 oxygen, whilst the average analysis in the same number of specimens of the Cardiff semi-bituminous coal, gives 88·15 carbon, 4·57 hydrogen, and 1·69 oxygen. From this it appears that the specimens from Newcastle, namely, the highly bituminous, contained 4·08 per cent. more oxygen, and ·75 per cent. more hydrogen (average amount) than the Cardiff, or semi-bituminous specimens. One of the qualities of coal suited to the steam navy, is stated, in the first report, to be that of burning "so that steam may be raised in a short period, if this be desired, or, in other words, that it should be able to produce quick action." This quality is considered as depending upon the

bituminous character of coals, the volatile gases being quickly evolved during the process of distillation. These gases ignite when at a temperature of about 2,000°. and continue to burn at a very exalted temperature, by means of which the rapidity of the combustion of the other constituents of the fuel is materially increased, and its available heat educed in a comparatively short space of time. But as "the greater the proportion of hydrogen contained in a fuel to that of oxygen, the more numerous are the combinations of carbon produced," it follows, that in the bituminous class of coals which we have noticed as containing 4·08 per cent. more oxygen than the semi-bituminous, the combinations of hydrogen and oxygen forming vapour of water will be much more numerous in the former than in the latter. Mr. C. W. Williams, in his work on "The Combustion of Coal and Prevention of Smoke," very properly observes, that the large cloud of smoke, which is seen to issue from the burning of highly bituminous coal, is simply steam coloured by floating particles of unburned free carbon. If this large amount of steam be produced at the fire-grate, or under the boiler used for steam purposes, a considerable quantity of the heat produced by the combinations of carbon, will be absorbed by it, and the useful effect of the fuel be thereby diminished. In Frederick Overman's Treatise on Metallurgy, pages 333 and 334, we read the following:—"In wood there is always a large quantity of water; this is converted into steam, and the heat absorbed, must be subtracted from the theoretic calorific effect. Anthracite coal should furnish the largest quantity of heat from the same weight of fuel, because it contains little hydrogen, and little air or water is contained in its pores. Bituminous coal should furnish an equally high temperature, and an equal amount of heat, as Anthracite; but this is not the case, chiefly on account of its softness and its volatile substances, which carry off a large quantity of carbon, which is either not burned at all, or imperfectly. Hydrogen does not furnish a high degree of heat, it gives off a large quantity, but not of good quality, and the apparently higher heat in the combustion of bituminous coal, compared with that of Anthracite or charcoal, is derived from the fine particles of carbon which float in the gas. Hydrogen absorbs a large quantity of

oxygen, and should furnish much heat; but the result of its combination is steam, which has a capacity for heat, four times greater than carbonic acid gas; it absorbs, therefore, four times as much heat as the latter, in order to be heated to the same degree—or what is the same thing, the temperature must be four times lower. Besides this defect of hydrogen, compared with carbon in respect to qualitative heat, its product of combustion is nearly three times as voluminous; the heat spreads, therefore, over a larger space, and, consequently, loses in direct proportion in intensity. These investigations show distinctly the superiority of carbon over hydrogen, and also over most other combustible substances." The degree of heat, at the point of combustion, with respect to the following substances, is represented thus;—

	DEGREES OF HEAT PRODUCED BY COMBUSTION.	
	In pure Oxygen.	In Atmospheric Air.
Carbon	17·770°	4·424°
Carburetted Hydrogen (Coal Gas)	10·843	3·829
Alcohol	8·137	3·438
Hydrogen	5·709	2·899

From these facts, we think it must appear evident that the relative heating power of coal is intimately connected with the proportion which the combinations of carbon sustain in the products of its combustion—"The less oxygen there is in fuel, and the more the hydrogen preponderates, the more numerous are the products of combustion, which this element forms with the carbon."—(Knapp's Technology, vol 1, page 58.)

Semi-bituminous coal is a variety of fuel, for the production of which some portions of the Sonth Wales coal field have gained considerable celebrity; and in this the port of Cardiff has shared, as being the place of its shipment. Another quality of coal, required by steam ships of war, is stated in the first report on the coals suited to the steam navy to be, "That it should not be bituminous, lest so much smoke be generated, as to betray the position of ships of war, when it is desirable that this should be concealed." One of the principal features of the semi-bituminous

coal is, that of being smokeless; on this account it is admirably adapted for all purposes, requiring a large calorific effect, without the nuisance and danger of smoke as a consequence. In speaking of the highly bituminous coal, we have endeavoured to show, on scientific grounds, why it may be expected to be somewhat inferior to the semi-bituminous variety in calorific effect; namely, because there are fewer combinations with carbon, and much more vapor of water, in the products of combustion of the former, than in those of the latter. By coupling with this the smokeless property of the semi-bituminous coal, we think that with respect to the absolute values of the respective coals for steam navigation and other purposes, the superiority of the semi-bituminous, over the highly bituminous, is fairly established. Very much merit is due to Mr. Williams, of Liverpool, for the able manner in which he has investigated the subject of "Combustion of Coal and Prevention of Smoke;" for this he was unquestionably deserving the £500 premium awarded him by the Steam Collieries' Association of Newcastle-upon-Tyne.

I must express my concurrence with two of the conclusions arrived at by the gentlemen appointed by the above association, to examine the steam coals of the Hartley district of Northumberland, as given in their second report—namely, 1st., That by an easy method of firing, combined with a due admission of air, and a proper arrangement of fire grate, the emission of smoke may be effectually prevented in ordinary marine tubular boilers, whilst using the steam coals of the Hartley district of Northumberland; and 2nd., That the prevention of smoke increases the economic value of the fuel, and the evaporative power of the boiler.

I wish particular attention to be given to the following phrases in the first conclusion—viz.: "Easy methed of firing," "due admission of air," and "proper arrangement of fire grate," as upon these conditions the prevention of smoke evidently depends. If the stoker should happen to "fire" a little too often, or somewhat over the required charge, the temperature of the escaping gases will be so reduced as to prevent their combination with the atmospheric oxygen at the inner extremity of the fire grate. Now, as the highly bituminous coals themselves differ considerably in the degree of

their bituminous properties, it will be a matter of no mean task for the stoker to so regulate the times between the charges, and the amount of each charge, as to give at all times "the easy charge" essential to the smoke's prevention. If too much air be admitted—that is, more than what is just necessary for the supply of the amount of oxygen required to effect perfect combustion, the surplus quantity will absorb heat, and thereby diminish the evaporative value of the fuel. Now, as the requirements of the burning fuel, for oxygen, must be ever varying with the various grades of bituminous quality in the coal, to secure a "due admission of air," the number or size of the apertures through which it is supplied, will be for ever requiring regulation. "Proper arrangement of fire grate," implies further regulation and increase of attention. Where the stoker is expected to attend to the due supply of these conditions, as being essential to the prevention of smoke, we may expect to see the tell-tale, either of his negligence, or of some derangement in the mechanism of the invention, making its smutty appearance at the chimney-top. The latter part of the third conclusion, given in the report, and the latter of two paragraphs which follow, are somewhat characteristic of the spirit in which, I am afraid, the reports and letters, recently published, respecting "the Hartley Steam Coals" have been written, they read thus—conclusion 3rd., "That the coals from the Hartley district have an evaporative power equal to the best Welsh steam coals, and that, practically, as regards steam navigation they are decidedly superior."

Paragraph 84—"This last conclusion is contrary to the general opinion, which, based upon the reports presented to Government by Sir H. De la Beche and Dr. Lyon Playfair, is strongly in favour of Welsh Coals."

Paragraph 85—"The effect of those reports has been to do the Northumberland Coal Field an immense injury; and we feel this so strongly, that we beg to lay before you a few observations on the subject, in a short supplementary report accompanying this."

I must confess that I should have had more faith in the correctness of their reports, had they been given apart from the strong feeling spoken of in the last paragraph; and the latter part of

the third conclusion—viz., "That highly bituminous coals from the Hartley district are practically, as regards steam navigation, decidedly superior to the Welsh semi-bituminous coals," is decidedly contradictory to the results of careful scientific investigation, and to extensive and authoritative experience.

The following results, taken from Government reports, are useful as showing the relative heating value of coals:—

	Carbon.	Hdrogn.	Oxygen.
(1) The Llangennech Coal (Welsh) contains	85·46	4·20	2·44
(2) Three-quarter Rock Vein (Welsh).....	75·15	4·93	5·04

You will perceive from the composition of 1, that it is of the semi-bituminous variety, and from that of 2, that it belongs to the highly-bituminous. Three litharge experiments with these two coals gave of lead as follows:—

	EXPERIMENTS.			MEAN.
	1st.	2nd.	3rd.	
(1)	163·4	163·2	163·0	163·3
(2)	133·0	133·2	133·2	133·1

These figures may be taken as representing the relative calorific value of the two coals, or whilst the calorific value of the most bituminous is 1·0, that of the other is 1·23.

The following results are according to Berthier:—

	lbs. of Lead reduced by 1 lb. of Coal.	lbs. of Waters heated from 0° to 100° c. by 1 lb. of Coal.
Coal from Dowlais (Wales).....	31·8	72·0
Glamorgan	31·2	70·7
Newcastle	30·9	70·0
Cannel Coal (Wigan.....	28·3	64·1
Cherry Coal (Derbyshire)	27·2	61·6
Cannel Coal (Glasgow)	24·9	56·4
Cannel Coal (Lancashire)	23·5	53·2

This table shows that the most highly bituminous coals are the lowest in calorific value.

The value of coal for steam and smelting purposes is very much affected by the quantity of iron pyrites (sulphuret of iron), it contains. The way in which this occurs in coal is also a matter of considerable importance. When disseminated throughout the mass in small grains or crystals, as in most of the anthracite and semi-anthracite coals, it rapidly decomposes on exposure to the atmosphere, and the resulting force of crystalization disintegrates and crumbles the hardest mass. But where it is in thin layers or bands in the cleavage planes of the coal, as in the free-burning bituminous coals of South Wales and of the North of England, although this same force must result from the combination of oxygen with the pyrites, the action is more confined and acts less injuriously on the coal, as it simply separates the coal by the cleavage planes instead of crumbling the mass.

In some of the semi-bituminous coals no pyrites can be observed. In a Report to Government, on a vein of smokeless coal, of about six feet in thickness, occurring in the Aberdare Valley, it is said that a considerable proportion of white substance was observed in the coal, but no pyrites; and several other coals of this variety are reported as containing "a very small quantity of pyrites," "very little pyrites," "pyrites in very minute quantities," &c. This is attested with respect to this kind of coal generally, by the fact, that from Merthyr (Westward) nearly all the furnaces on the South Wales Coal Field are now using raw coal. The value of coal for smelting purposes does not, however, depend entirely upon the absence of iron pyrites, but also to a great extent upon its mechanical structure, and the chemical composition of the ash The "Comparative values of different kinds of Coal for the purpose of Illumination," was very ably investigated by Dr. Andrew Fyfe, Professor of Chemistry in King's College, Aberdeen, in a paper read before the Scottish Society of Arts, in 1848. In that paper he observed that, "In estimating the qualty of coal-gases, and consequently fixing their comparative value for the purposes of illumination, we

must take into account both the light afforded, and the time required for the consumption of equal volumes," and, guided by these aims, he discovered that the value of fuels, for gas making, or for the purpose of illumination, was in the proportion of the amount of oxygen they contained, or to the degree of their bituminous quality. This value, in what he designated the English Caking Coal, was indicated by 4·33, and in the Yorkshire Cannel by 7·66, their durabilities being 50' 30" and 52' 30". This gives a proportion of 1 in the former to 1·81 of the latter. The Wigan Cannel gave 1·85 to 1 of English Caking Coal, and the value of the gas from Lesmahago Coal, which, by gas makers, was generally considered the best in the market, was as 6·6 to 1 of the English Caking Coal Gas, and as 2·6 to 1 of the English Cannel.

The Anthracite Coal is remarkable for a very high per centage of carbon. Some of the minerals to which this name has been appropriated, because of the similarity in the external appearance, and the smallness of the difference in physical character and properties to the anthracites of the vegetable series, are very probably purely mineral, that is, not of vegetable origin as the coals proper unquestionably are. Owing to the compact structure of most of the anthracites, they ignite slowly, but when once ignited they give out an intense heat, sufficiently so to melt the fire bars, except great care be exercised in firing. The anthracite coal, from the parish of Llanguicke, in Glamorganshire, which is described in the Government Reports as being of a hard structure, but, from its brittle character, broken without difficulty, was observed in the experiments for the Steam Navy to require nearly three hours for becoming sufficiently kindled to raise the steam. "The quantities of cinders and ashes were larger than with many other coals; they were of very small size, and both contained, when broken up and examined, varying proportions of pure and unaltered coal, surrounded by the burnt mass." Some of the anthracites, however, from their great purity, and solidity of form, are remarkably well adapted for metallurgical operations. "The ultimate analysis of anthracite, from Pennsylvania, gave 94·1 carbon, 2·39 hydrogen, ·87 nitrogen, 1·33 oxygen, and 1·3 ash. The ashes, like those from

bituminous coal, generally consist of silica, alumina, oxide of iron, sulphur, and chlorides, which evaporate and condense on cold objects, in the form of white films. It is found that a reverberatory furnace, with a low roof, is of the best construction for the use of anthracite, as the current of blast is thereby more confined, and hence sufficiently increased in force to prevent the floating luminous particles of carbon from being deposited on the hearth."*

Coke, of the best quality, will undoubtedly long continue to be a requirement with the operator in metals, and the conversion of small coal into coke, of even a somewhat inferior quality, a means of profit to the coal master; but I am persuaded that a proper division and appropriation of the various fuels, as furnished to us by nature, will, in course of time, greatly lessen the necessity for coke. We, no doubt, have fuels in their raw or natural condition, having their peculiar adaptations to all the purposes of the engineer and the smelter; and very much of the time and expense devoted to the discussion of the fitness of several kinds of fuel for one purpose, might, probably, have been more profitably exercised in investigating the peculiar adaptations of the respective fuels to the various purposes for which fuel is required. The South Wales coal field seem to be peculiarly favoured with respect to variety of coal. We have already made allusion to its anthracites and semi-bituminous varieties, and on the authority of a gentleman of honourable position amongst us, for whose kind assistance in this and other matters, I am glad of this opportunity to acknowledge, it appears that all the coals—namely, those of the Pennant or Micaceous Sandstone Rocks, are every where over the coal field of a highly bituminous character, the most bituminous being a seam worked in Monmouthshire, under the name of "The Mynyddysllyn Vein," and in Glamorganshire, under the names of "The Gellygaer" and "Lantwit Coal." This coal leaves a red ash, and brings the highest price as a house coal.

I beg to submit the following leading article, taken from the *Mining Journal*, of 15th May, 1858, as an appendix to this paper :—

* Overman's Metallurgy.

"Science teaches us that no Force can be produced without change in the Material world. We do not purpose here to follow this subject, and treat of the beautiful and highly philosophic researches of the illustrious Faraday, on the 'Indestructibility of Force;' we must confide ourselves to much narrower and more practical views of the subject.

"The force which moves the gigantic steam-engine, the swift locomotive, the tiny needle of the electric telegraph, the sturdy arm of the labourer, the delicate finger of the engraver, and the pen of the writer, is alike eliminated by one process in Nature we term 'chemical decomposition;' the coal for the steam-engine, and the bread for man, may be truly named the food by which their force is produced.

"If, as some political economists assert, we employ in Great Britain power and machinery to perform work equivalent to 80,000,000 of men, and our superiority and national existence depend upon the maintainance of this working power, how serious a subject is the continued and economic supply of coal, which is now its source. We resume the subject in a practical form, and confine ourselves to the coal used for steam purposes, and more especially for marine engines. The varieties of coal adapted for this use may be classed as—anthracite, semi-anthracite, and free burning; these differ from each other respectively in chemical composition and mechanical structure, and, so far as we at present know, no one form of grate is adapted to consume them all, in an equally efficient manner.

"The reports of Sir H. De la Beche and Dr. Lyon Playfair on this subject have been much underrated, and, we think in some cases, dealt with unfairly. On comparing these reports with those of the United States Government, and others on the like subject, we are compelled to admit their great ability and general truthfulness. The complaint in the late reports of Messrs. Armstrong, Longridge, and Richardson, as to the partial character of the experiments at the Museum of Practical Geology, we cannot consider as strictly correct: we forbear at present any further criticism on

these latter, but advise our readers who are interested to read both series for themselves. To every thoughtful mind it will be plain that in the former reports every detail is given as to the exact manner and condition under which the experiments were performed; and there is no attempt at 'special pleading' in favour of any particular coal.

"The scientific part of these reports no one seems to have attempted to contradict; it may have been imprudent in Messrs. De la Beche and Playfair to have followed the subject further than the mere scientific investigations; but by the instructions they received (see pages 1 and 2, Report I.), they were directed to try to ascertain the then practical value of the steam coals of Great Britain: to ascertain this practical value they could only take for experiment the character of boiler and grate which was then in actual use in the steam navy; and this, as we shall afterwards prove, they did.

"These gentlemen were not directed to speculate what might be done in future by the use of improved boilers and fire grates, but what could be done then by the steam navy. The correctness of the scientific part of their reports proves fully they well understood the subject they dealt with.

"We select some varieties of the best steam coals, analysed in these investigations, belonging respectively to different districts in this country, and to show how nearly they approach each other in theoretical and true value, we give the following tabular statement. As the values of all are not shown in the Government Reports, we take the analysis as we find them in these reports, and reduce them by Dulong's formulæ.

Description.	Character of Coal.	Number of lbs. of water convertible into steam by the carbon of 1 lb. of the coal.	Number of lbs. of water convertible into steam by the hydrogen of 1 lb of the coal.	Total number of lbs. of water converted into steam by 1 lb. of coal.
South Wales.—Anthracite, Jones, Aubrey, and Co	Anthracite	12·563	2·030	14·593
Duffryn, Powell	Semi-anthracite	12·126	2·966	15·092
Ebbw Vale	Free burning	12·335	3·300	15·635
North Wales.—Coleshill	ditto	10.145	2·658	12·803
Brymbo Main	ditto	10·698	2·522	13·220
Brymbo Two-yard	ditto	10·734	2·930	13·664
North of England.—Willington	ditto	11·926	2·788	14·714
Andrew's House, Tanfield	ditto	11·757	3·079	14·836
Broomhill	ditto	11·225	3·638	14·863
Lancashire.—Blackbrook, Little Delf	ditto	11·362	3·195	14·557
Ince Hall, Pemberton Yard	ditto	11·098	3·422	14·520
Ince Hall, Arley	ditto	11·350	3·189	14·539
Scotland.—Wellewood	ditto	11.178	3·541	14·719
Fordel Splint	ditto	10·933	2·884	13·817
Grangemouth	ditto	10·970	2·722	13·692

"The boiler they selected for the practical trials was a fair type of the form then most in use in the navy. Since that time the multitubular boiler has become the general form; and as the semi-anthracite coals seem to be most easily dealt with under this, they have, during the last few years, come largely into use; but we cannot doubt the fact that some improved boiler or grate may soon again displace these latter variety of coals from the high position they now hold. Whether the late experiments, as reported by Messrs. Armstrong and others, show how this can be done, we do not at present decide: the steam companies of Great Britain are the jury empanelled to try this case, and will, no doubt, in the end give a just verdict.

"We will briefly review some of the practical points of difference in the steam coals of this country. The only districts where coals are produced to any extent for marine purposes are Scotland, the North of England, Lancashire, North Wales, and South Wales. The principal difference in the practical value of all these coals arises from their physical structure. The Scotch coals are free burning, and, like all this variety, give off smoke, if air be not properly admitted in the fire grate; they burn rapidly, and, unless great care is used in the stoking, are very wasteful under short tubular boilers; they work well for short voyages, where tonnage room is not of much value. The North of England coals are free burning, bear exposure to the weather, break readily in pieces of a fit size for firing, and do not give much small or dust, and are entitled to much of the merit claimed for them in the report of Messrs. Armstrong and others to which we have referred. The Lancashire and North Wales Coals are free burning, and in the trade are classed nearly as the Scotch Coals. The South Wales Field contains all the varieties of steam coals. Commencing at the western end, in the neighbourhood of Milford Haven, we find anthracite, and this extends eastward to the Vale of Neath. We now come to a semi-anthracite coal, and follow this to the Rhymney Valley, where it becomes free burning, and then on to Blaenavon, where it becomes almost too bituminous for steam purposes.

"Much has been said of the superior value of anthracite coal—its purity, freedom from smoke, and the large amount of carbon it contains, and all these good qualities we must admit; but in practice the public have so far not been able to obtain the advantage of them. The compact mechanical structure of the coal prevents its rapid combustion under the boiler, and the intense local heat it gives off is, without great care, apt to melt the fire bars; and some special form of grate, and very careful firing, being required in its use, it has not yet been largely consumed. The semi-anthracite coal was introduced a few years since, just at the time when multitubular boilers were coming into use for marine engines; and as it possessed some qualities which met the exact requirements of the time, it has been very largely used, and obtained a high reputation. This class of coal gives very little smoke in burning, does not require much skill in stoking, and produces a hot flame, well adapted for short boiler flues or tubes; its disadvantages are, however, serious. It is said to crumble, or decrepitate, by the action of the weather, and the small will not burn in the grate; much of it contains large quantities of pyrites, which not only reduces its available heating power, but rapidly destroys the boilers and fire bars; still it is a favourite, and no doubt a valuable steam coal. The free burning coal of South Wales was the earliest used for steam navigation. A series of experiments were first made at Bristol, on the practical economic value of different varieties of coal for steam navigation, the result of which was to determine the coal to be used in the *Great Western* steam-ship on her first voyage. The decided superiority of the Welsh free-burning coals, under the shaped boiler they then used, was unexpected; and its economy in raising steam completely satisfied the projectors as to the successful result of their enterprise.

"Many of us well remember the national joy upon the return of the *Great Western* from New York, and, as was then aptly remarked, 'having carried a steam-bridge over the Atlantic.' The coal used in this ship was from the Tredegar Valley. Ocean steamers were soon multiplied; the West Indian Royal Mail Company;

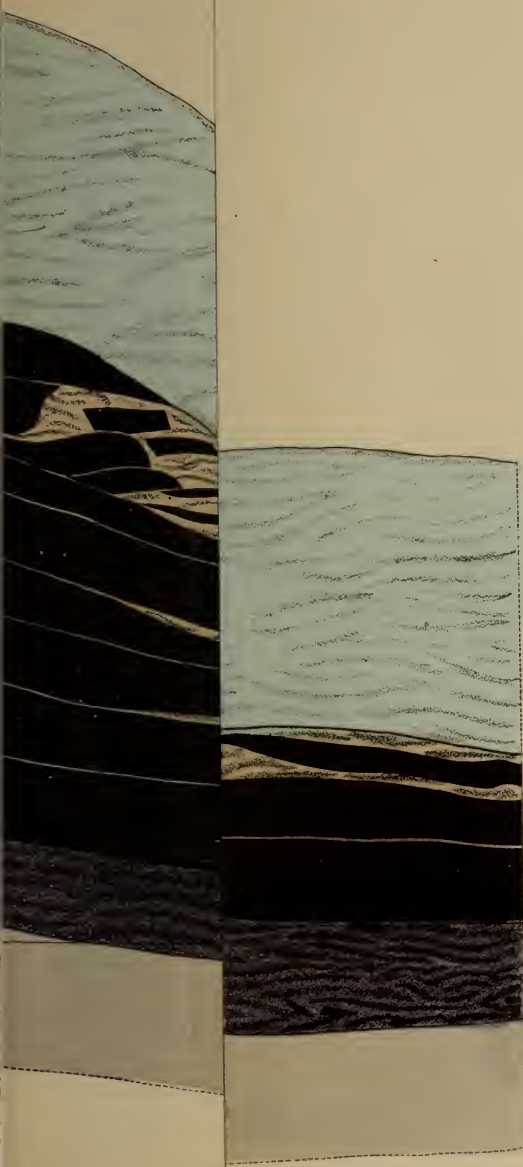
Cunard's Line; the Peninsular and Oriental Steam Company, and others, were large consumers of steam-coal, and thus this important trade was gradually developed. For a time the coal of South Wales was the only variety believed to be suitable for ocean steam navigation, and that district obtained a monopoly of the trade.

"The scientific and mechanical engineers have already taken up this subject, and show us plainly that they are able, to some extent, to follow out the facts eliminated by the men of chemical science, and other coals can be advantageously used. At the same time, we must not conceal the fact that, theoretically, the free-burning coals of South Wales stand first on the list; and practically they do so also. The Ebbw Vale Works are now sending by rail to Liverpool, over a distance of 150 miles, large quantities of coal to supply the British and American ocean steamers; and experience seems to teach these Companies that the greatly higher price paid for these coals is true economy, as they are used under their present boilers. Our aim is not to advance the claims of any particular district, or even to judge between the public and the steam coal proprietors; we try to elucidate the matter by plain and practical remarks, and induce men to work it out. Our columns are always open to discussion on this point, and we do our duty to society in claiming thoughtful attention to this important subject."

Mr. Cox expressed his regret, that a paper on such an important subject, and on which so much labour and research had evidently been expended, should have been read at so late an hour, but he could not allow it to pass without noticing some grave errors which he conceived it contained

The President said that if Mr. Cox wished to have the paper discussed, which the late hour rendered impossible at that time, he could have it so by bringing it forward again; by writing a short paper on the subject.

As this appeared to meet the approbation of the meeting, Mr. Cox assented to do so; and after a vote of thanks to Mr. Fryar and the President, the proceedings terminated.

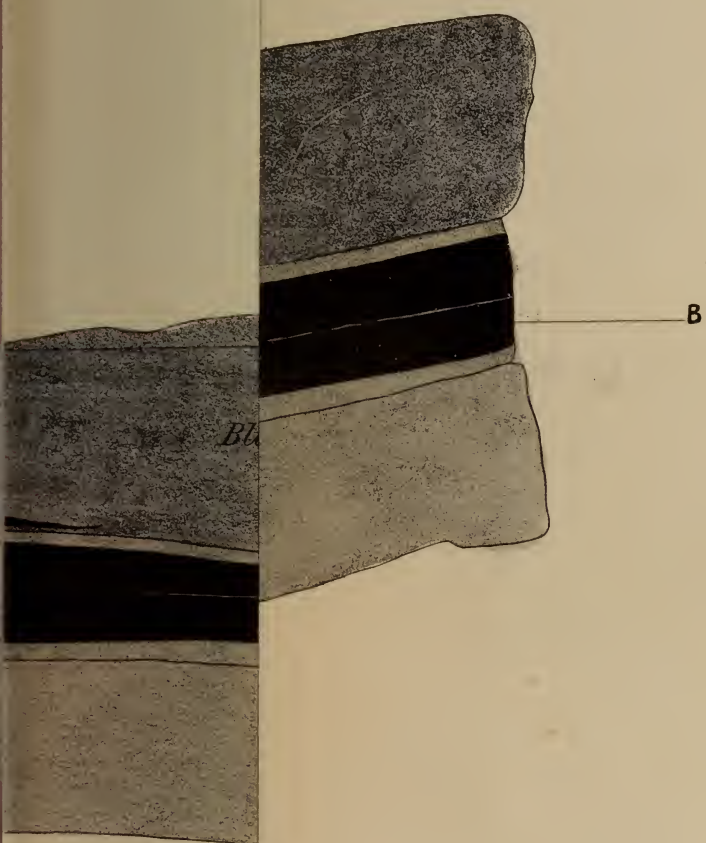


SECTION OF THE BULL VEIN

IN A HEAD 450 YARDS S. 24° E. FROM MIDDLE PIT

RADSTOCK COLLIERIES.

SCALE. ½ INCH TO A FOOT



SCALE,
2 3 4 5 6

SECTION OF THE BULL VEIN

IN A HEAD 290 YARDS SOUTH 51° WEST FROM THE

WELLS WAY PIT

RADSTOCK COLLIERY.

Direction of Section South 14° West.

SCALE,

Inches 12 6 0 1 2 3 4 5 6 7 8 9 Feet.

NOTE. *At the points A & B. the Vein is in its ordinary state.*

SECTION AT B

Roof Blue metal.	
Rubbish	0'. 2".
Coal	1'. 1".
Parting	0'. 0".
Coal	1'. 3½.
Total,	2'. 6½.

Thill Black metal.

NEUROPTERIS GICANTE

Roof of Slyving Vein, Wells W

ECOPTERIS { HETEROPHYLLA
AQUILINA.

ing Vein, Wells Way Pit, Radstock.

NEUROPTERIS GIGANTEA

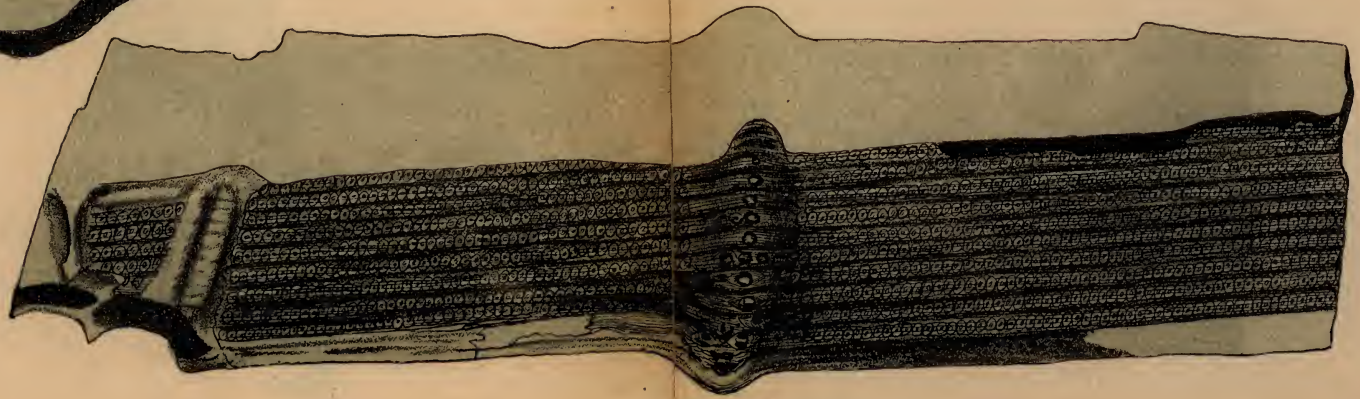
Roof of Slyving Vein, Wells Way Pit, Radstock.

PECOPTERIS { HETEROPHYLLA / AQUILINA.

Roof of Slyving Vein, Wells Way Pit, Radstock.

CAULOPTERIS PRIMÆVA.

Roof of Great Vein, Tyning Pit, Radstock.



SIGILLARIA.

Roof of Bottom Little Vein, Middle Pit, Radstock.

ETIFORMIS.
e Pit, Radstock.

SPHENO
Roof of Bull Vein

ASTEROPHYLLITES EQUISETIFORMIS.
Roof of Top Little Vein, Middle Pit, Radstock.

SPHENOPHYLLUM SCHLOTHEIMI.
Roof of Bull Vein Seam, Wellsway Pit, Radstock.

SPHENOPTERIS ?
Roof of Bull Vein, Old Pit, Radstock Colliery.

NEUROPTERIS { HETEROPHYLLA
ACUTIFOLIA.

PROCEEDINGS.

19th January, 1859.

The General Meeting of the Members was held at the Castle Assembly Room, Merthyr-Tydfil, on Wednesday, 19th January;

Mr. E. Rogers, the President, in the Chair.

The Minutes of the October Meeting were read and confirmed.

The President stated that at the last meeting, Mr. Cox had been requested to introduce the adjourned discussion on Mr. Fryar's paper, by reading a short paper on the same subject. He was sorry Mr. Fryar was not present. The Bristol School of Mines, of which Mr. Fryar was Principal, was being this week examined by the Government Inspector, and he was not able to come to the meeting. The discussion would be looked upon in this district, and in very many parts of the kingdom, with great interest; for, at present, a very large proportion of fuel was wasted, from a want of knowledge how best to use it. This was of vast importance, when

it was remembered that we consumed, annually, sixty-three millions of tons of coal; and, that the power given by this, was one of the sources of our national greatness. We wanted a knowledge of how to comply with the natural laws of combustion. If these papers and discussions threw some light on the subject, the Institute would, to some extent, have promoted the progress of civilization, and have deserved well of the country. He suggested, that it would be more satisfactory that Mr. Fryar should be present when his paper was discussed, in order to answer objections, and give explanations if necessary.

The following paper was then read:

ON THE COMBUSTION OF COAL.

By MR. COX.

There are few subjects which have a more legitimate claim for general consideration than the economic use of our mineral fuel : there are few which it may be supposed scientific minds would be more desirous of imvestigating than the phenomena attending its combustion; not only on account of the vast importance of the subject, but also because it is one in which science is unquestionably at fault when endeavouring to account for the paradoxes they exhibit: and there is nothing in which this Institute would be expected to take a greater interest, than that part of it which relates to the question of the superiority of the peculiar varieties raised in this locality, (the semi-bituminous and semi-anthracitical coals,) as compared with the bituminous varieties of the North of England.

These considerations caused me, at the last meeting of the Institute, to hear, with feelings of regret, a paper, on this important subject, read at so late a period of the meeting as to preclude the possibility of its being discussed; conceiving that it would little accord with the avowed objects of this Institute, for it to pass by the subject, or its mode of treatment, as unworthy of notice, or to send forth the paper to the world with our tacit assent to all the dogmas it contains. With the view, therefore, of commencing a discussion, which I sincerely hope may ultimately lead to a thorough investigation and knowledge of the subject, I acceded to the suggestion of the President to bring it forward again by writing a supplementary paper on it; a course which, though unusual, and, in many respects undesirable, was, as it appeared at that moment, the

only one which would enable us to obtain, what the meeting appeared also to desire, a discussion on the subject.

Whatever may be the cause, the fact is unquestioned, that the union of oxygen with most, if not all, other bodies produces heat; and, though we speak of such bodies as combustibles, and reckon their value by the heat given out by what we denominate their combustion, it is the generally received opinion, that the heat is derived from the oxygen and not from the body uniting with it; and we suppose, therefore, that the heat created should be in proportion to the quantity of oxygen with which the so called combustible is capable of uniting.

Supposing, therefore, that the chemical union or combustion was in both cases perfect, hydrogen should produce three times the heat which carbon could elicit, as it will absort three times as much oxygen as the latter is capable of taking up, even when it unites with the double dose in forming carbonic acid.

This theory, as far as hydrogen is concerned, is more than borne out by the experiments of chemists, as it has been found to create about 4.5 times as much heat as carbon; which may be accounted for by supposing that some large allowance should be made from the results of these experiments, for the heat required to volatilize the solid hydrogen as it exists in coal; the experiments having been conducted with hydrogen in the shape of gas as against solid carbon: or that the comparative deficiency in the heating power of carbon was to be attributed to the greater heat absorbed in the volatilization.

The volatilization of carbon necessarily takes place in its first combustion, or the formation of carbonic oxyde, and we should, therefore, anticipate to find the deficiency in its heating powers, in the production of this union; a theory in which we are supported by Dulong and Andrews, who both coincide in giving the heat produced by the second combustion of carbon, (that is the formation of carbonic acid from carbonic oxyde,) as rather more than two-thirds of the total heat evolved by its perfect combustion; and as nearly

as possible one-sixth of that produced by hydrogen, which is the exact proportion as compared with hydrogen, theory would have led us to expect. Whatever heat, therefore, we may conceive that our experience in the evaporation of water may justify us in considering hydrogen would absorb to volatilize it, we have here a proof that carbon does require a very large amount, a point to which I ask your attention, when estimating the loss due to the volatilization of a part of the contents of the coal, to which I shall presently more particularly allude.

However we may endeavour to account for the experienced superiority of the heating power of hydrogen as compared with that of carbon, over what may have been anticipated; whether we take the value of those two combustibles by theory or experiment, the larger value of hydrogen is apparent; and it would be difficult to arrive at any other conclusion than that, in estimating the value of the hydrocarburets, it must be fairly taken into account, (unless we can understand in what way its heat producing properties have been rendered inoperative); although, whether we are to reckon it according to its estimated theoretic heating power of three times, or to the experimental result of 4.5 times, that of carbon, is a question that may be open to dispute. That no loss of heat in its combustion has to be feared on account of the greater capacity for absorbing heat of the product of its combustion, (vapour of water), over carbonic acid gas (the product of the combustion of carbon), is evident from the results of the experiments of the eminent chemists who have devoted themselves to the investigation of this subject; as whether in the shape of hydrogen unmixed with carbon, of marsh gas, or of carburated hydrogen, the result of its evaporating power is in excess of what theory would have anticipated, (as compared with the heat produced by the combustion of carbon); thus shewing that there is no deficiency which we need seek to account for by attributing it to this cause.

The quantity of ash contained in any coal must necessarily diminish the amount of combustible matter. This is easy of calculation, or rather it does not require to be taken into consideration if

we calculate the heat producing powers of the carbon and the hydrogen; the nitrogen may be also thrown aside, and so is generally the sulphur, (whether rightly or not I shall not now seek to discuss); the only other constituent of coal is oxygen, which exists in a great variety of proportions from .39 per cent. in the Ebbw Vale Elled, to 15 and even 20 per cent., and more in some other varieties. It would seem to be assumed by Mr. Fryar, as an established fact, that this is a heat producing constituent; and, as it is to this dogma I take exception, I shall dwell a little on the subject.

If we are to suppose that the oxygen contained in the coal, plays the same part, and gives out the same heat, in its union with the carbon, or hydrogen, as the oxygen of the atmosphere, (and I have never heard it asserted that it gives out more,) it is utterly worthless; as the carbon or hydrogen would have taken the same quantity of oxygen from the atmosphere, and produced the same amount of heat in its combustion if it had not been there. To the extent, therefore, of its presence, would it be injurious, as necessarily diminishing the quantity of carbon or hydrogen, and, like the ash, might be thrown out of the calculation; the calorific value of the coal would still be measured only by the amount of its carbon and hydrogen. But I cannot accept this theory: I conceive that its union with either the carbon or hydrogen, or both, must have taken place before it could exist in the solid form in the coal, and that in that union it gave out all the heat it was capable of evolving. In this view I am supported by De la Beche and Playfair, who, in calculating the theoretic value of coals from the carbon and hydrogen they contained, deducted from the amount the hydrogen which the fixed oxygen would neutralize; taking it for granted, I presume, that it was the hydrogen it united with. It would make no difference as to the amount of heating power it would neutralize, whether it united with the hydrogen or carbon, but it would make a great difference in the amount of solid matter to be volatilized.

In my experience and experiments in gas making, I have found that the water, (which I take to be hygroscopic water), is volatilized at a low heat, at the earliest part of the process of distillation;

but that the carbonic oxyde, (which I conclude to be produced by the union of the fixed oxygen), is produced generally at the last part of the process, and at the greatest heat; and I infer, therefore, that it requires, and absorbs, so great a heat to produce its volatilization, as to form an important item in calculating the theoretic heating power of the coal; and that, as it exists in the largest quantity in the most bituminous coals, we may reasonably attribute to the heat required to volatilize it, and the carbon it carries off, a great part of the deficiency of the heat produced by these coals over that which the amount of carbon and hydrogen contained in them might have led us to anticipate.

It is the common error to suppose that the bituminous coals contain a much larger quantity of hydrogen than the semi-bituminous, and that a great deficiency in their theoretic heating powers, is practically experienced in their combustion; which has also given rise to the idea, that if the amount due from this imagined excess of hydrogen, could be realized, the bituminous coals must necessarily be superior to the semi-bituminous.

So far is this from being the case, that the fact is, that the small apparent excess is not equivalent to the deficiency of carbon. Taking the average of ten samples of each sort, as quoted by Mr. Fryar, the excess of hydrogen, in the Newcastle coals, is only .75 per cent., equal to 2.25 caloriferes, (taking that of carbon as 1,) while the excess of carbon, in the Welsh coal, is 5.30, making a difference in favour of the latter of 3.05; and if we follow the example of De la Beche and Playfair, and add to this 1.53, the calorific value of the hydrogen neutralized by 4.08, the excess of oxygen in the Newcastle coals, we have a total difference of 4.58 caloriferes against them.

That there is a great difference in the experienced heating powers of the most bituminous varieties, over even the small amount which theory has, I believe erroneously, allotted them, is certainly the case; but, my object is to shew, that the greater part of this apparent deficiency can be clearly accounted for, so as, to that extent, to render its reduction altogether hopeless.

I now approach a part of the subject, which (as it appears to place me in an antagonistic position to two gentlemen, whose names justly command the highest respect,) I am very diffident of handling. In the first report on Steam Coals to the Admiralty, appears this passage:

"The only omitted correction, which, in appearance, might be "supposed necessary for practical purposes, is that of the hygro- "scopic condition of the fuel. Had wood been employed, this must "have been done; but the hygroscopic nature of coal is very much "less than that of wood. The latter contains one-fifth of its own "weight of hygroscopic water; and the heat necessary for the "evaporation of this quantity, might be shewn, by a simple calcu- "lation, to be nearly equal to 22 per cent. of the total heat obtained "by the combustion of the wood. The hygroscopic water in coal "is, however, very small, as will be seen by the following deter- "minations of some of the Welsh specimens experimented upon.

	Hygroscopic Water.
"Graigola coal	1.06 per cent.
"Anthracite	2.44 "
"Old Castle	0.74 "
"Ward's Fiery Vein.....	1.27 "
"Myndd Newydd	0.67 "
"Pentrepoth	0.78 "
"Pentrefelin	0.70 "

"Had we introduced corrections for these small quantities, practice "would have been misled; because the coals will rarely reach a "vessel in the dry state that they did in the present case, when they "were packed in hogsheads, and kept under cover."

Aware, from my experience in gas making, that the hygroscopic water, in bituminous coals, often exceeded 5 per cent., I read this paragraph with surprise; and eagerly turned to the third report, where I found, that, so far from the above statement being borne out, in the analysis of nine out of the ten sorts of those coals referred to by Mr. Fryar, (I could not find the details of the tenth), the average quantity of hygroscopic water, was 4.50 per cent., as against 1.21 in nine out of the ten sorts of Welsh coals; although in the best varieties, it was as low as from 1.33 to 1.46 per cent.;

while in the analysis of five other varieties, not included in the ten above quoted, its amount was as follows:

	Hygroscopic Water.
Cowpen and Sidney Hartley ...	10.17 per cent.
Original Hartley	8.11 "
Broomhill	9.31 "
Derwentwater Hartley	12.52 "
North Percy Hartley	8.41 "
	48.52
Making an average of.....	9.70

Now, as the coal experimented on, contained this enormous amount of admitted deleterious matter, while the analysis from which its theoretic value was calculated did not contain it, it seems incredible that gentlemen who appreciated its injurious effects so highly, could have overlooked it; and I have again and again read their reports to assure myself that it is so.

As it is in the most bituminous coals that the greatest discrepancy appears between the actual performance and the theoretic value; and as it is only by bringing the former up to the latter that these coals can ever come into favourable competition with the semi-bituminous for steam purposes; let us see what amount of this deficiency may be accounted for by the presence of oxygen and hygroscopic water; and what will be then left as a margin to be realized by improved combustion; or to be still further reduced, or perhaps wholly absorbed, by deducting the heat required to volatilize the carbonic oxyde, (resulting from the union of the fixed oxygen,) and the hygroscopic water.

To make this the more intelligible, let us take the extreme cases of the coals of the largest and smallest heating powers by experiment—the Aberaman Merthyr, and Cowpen and Sidney Hartley. The theoretic calorific value of the gross amount of the carbon and hydrogen of these two; calculating that of carbon as 1, and that of hydrogen as 3, is

Merthyr, 103.78—Hartley, 97.50,

Making a difference in favour of Merthyr of only

6.28 caloriferes, or 6.05 per cent.,

Whereas the actual relative evaporating power by experiment was

Merthyr, 10.75—Hartley, 6.79,

Being a difference of

3.96 or 36.83 per cent.

But if, in making this analysis, we had operated upon the coal in its natural state, (that in which it is ordinarily burnt), the quantity of carbon and hydrogen would have been reduced in proportion to the quantity of hygroscopic water, and the difference in the theoretic value would have been proportionately greater, approximating much more nearly to the experimental results.

The analysis of the two coals would have then stood thus,

	Carbon.	Hydrogen.	Oxygen.	Water.
Merthyr	90.56	4.26	.93	.41
Hartley	73.84	4.58	7.15	10.17

And the relative theoretic value of the gross amount of carbon and hydrogen would have been,

Merthyr, 103.34—Hartley, 87.58,

And of the carbon and hydrogen, deducting the quantity neutralized by the oxygen,

Merthyr, 103.01—Hartley, 84.91,

Giving a difference of theoretic value of,

18.10 or 17.56 per cent.,

Instead of 6.28, or 6.05 per cent.

The theoretic difference of the value of the gross amount of carbon and hydrogen, and accounting for very nearly half of the experimental result of

39.6 or 36.83 per cent.

Now, as we must deduct from the residue a large, although, at present, an unascertained quantity for volatilizing not only the hygroscopic water, but also the fixed oxygen, and its accompanying hydrogen or carbon (which I have already shewn must be very large), it is easy to judge what probability there is of ever removing any large portion of the 36.84 per cent. difference, at present existing, in the apparent value of the two coals.

The annexed table, shewing the difference between the theoretic value of the desicated coal, as contrasted with the theoretic value of the coal in its natural state, and the experimental results, may prove not uninteresting.

TABLE OF THE

COMPARATIVE THEORETIC & EXPERIMENTAL CALORIFIC VALUE OF COALS,

CALCULATING CARBON AS 1, AND HYDROGEN AS 3.

	Quantities of Carbon, Hydrogen, and Oxygen, in Coals from which the Hygroscopic Water has been expelled.—From Admiralty Analysis.			Hygroscopic Water.	Quantities of Carbon, Hydrogen, and Oxygen, in Coals, in their natural state, containing Hygroscopic Water. Calculated from Admiralty Analysis.			Comparative Theoretic Calorific Value of Coals, after Hygroscopic Water is expelled.	Comparative Theoretic Calorific Value of Coals in their Natural State.	Comparative Evaporating Power by Experiment. —— lbs. of Water Evaporated by 10 lbs. of Coal.
	Carbon.	Hydrogen.	Oxygen.		Carbon.	Hydrogen.	Oxygen.			
Aberaman Merthyr	90.94	4.28	.94	.41	90.56	4.26	.93	103.43	102.99	107.5
Ebbw Vale.....	89.78	5.15	.39	1.34	88.57	5.08	.38	105.08	103.67	102.1
Thomas's Merthyr.....	90.12	4.33	2.02	1.42	88.84	4.27	1.99	102.36	100.90	101.6
Duffryn	88.26	4.66	.60	1.13	87.26	4.60	.59	102.03	100.85	101.4
Nixon's Merthyr.....	90.27	4.12	2.53	1.22	89.16	4.07	2.50	101.70	100.44	99.6
Bedwas	80.61	6.01	1.50	1.28	79.57	5.93	1.48	98.10	96.82	97.9
Hill's Plymouth	88.49	4.00	3.82	1.26	87.37	3.95	3.77	99.08	97.81	97.5
Aberdare Co.'s Merthyr	88.28	4.24	1.65	1.40	87.04	4.18	1.62	100.38	98.97	97.3
Willingden.....	86.81	4.96	5.22	1.11	85.84	4.90	5.16	99.74	98.62	99.5
Andrew's House.....	85.58	5.31	4.39	6.58	79.94	4.96	4.10	99.87	93.29	93.9
Bowden's Close	84.92	4.53	6.66	1.33	83.79	4.47	6.57	96.02	94.74	93.8
Haswell's Wallsend	83.47	6,68	8.17	4.08	80.06	6.40	7.83	100.45	96.33	88.7
Newcastle Hartley.....	81.81	5.50	2.58	1.38	80.68	5.42	2.54	97.34	95.99	82.3
Hedley's Hartley	80.26	5.28	2.40	1.46	79.08	5.20	2.36	95.20	93.80	81.6
Bates's West Hartley.....	80.61	5.26	6.51	9.28	73.13	4.77	5.90	93.95	85.23	80.4
Buddle's West Hartley	80.75	5.04	7.86	7.24	74.90	4.67	7.29	92.93	86.20	78.2
Hastings's Hartley.....	82.24	5.42	6.44	7.88	75.76	4.99	5.93	96.09	88.51	77.7
Carr's Hartley	79.83	5.11	7.86	5.60	75.35	4.82	7.41	92.22	87.04	77.1
North Percy Hartley.....	80.03	5.08	9.91	8.41	73.29	4.65	9.07	91.56	83.85	75.7
Derwentwater Hartley	78.01	4.74	10.31	12.52	68.24	4.14	9.02	88.37	77.30	74.2
Broomhill	81.70	6.17	4.37	9.31	74.09	5.59	3.96	98.57	89.39	73.0
Original Hartley	81.18	5.56	8.03	8.11	74.59	5.11	7.37	94.85	87.16	68.2
Cowpen and Sidney Hartley ...	82.20	5.10	7.97	10.17	73.84	4.58	7.16	94.53	84.91	67.9

The PRESIDENT said that in consequence of the length of time required to prepare the diagrams, &c., appertaining to the proceedings of the last meeting, the papers read at Cardiff had not been delivered until this morning, and, therefore, the very able paper that had raised the questions now before the meeting had not yet been placed in the hands of the members. In a few weeks they would also have the excellent paper just read, by Mr. Cox, and he would suggert the postponement of the discussion until the next meeting, when all the members would have had an opportunity of reading both papers, and Mr. Fryar would probably be present.

MR. ROPER thought it would be best to adopt the suggestion of the President. The papers were of such importance that they deserved the fullest discussion, and it was desirable that the writers should be present to defend the opinions they had advanced. It was a question of great importance to all to ascertain which coals were of the greatest practical value. He moved that the discussion be adjourned to the next meeting.

MR. CLARK remarked that the experiments recently made at Cardiff fully bore out the superiority of the South Wales Steam Coals.

MR. R. H. RHYS would second the motion for the adjournment of the discussion. It was most desirable that the members should be able first to compare the papers. If his memory served him rightly Mr. Fryar had arrived at the same conclusion as Mr. Cox, but in a different way. Motion carried.

The following Paper was then read:—

THICK AND THIN FIRES, BY PROFESSOR JOHNSON.

Communicated by Mr. W. S. CLARK.

This is a subject of so much practical importance that I have thought it right to submit for your consideration a few remarks thereon, contained in a Letter of Professor J. R. Johnson, dated 1843.

In considering this subject we find at the outset the following questions, namely :—

What depth in inches constitutes a Thick, and what a Thin Fire?

What is the Draught, and what is the Nature of the Fuel?

We will assume that more or less perfect combustion depends on the proportion of the surface of incandescent coke to the quantity of air impinging upon it in a given time. The nature and quality of the fuel will necessarily materially influence the determining of the depth or thickness. For perfect combustion, by which is meant the combustion of greatest economy, the surface of which will always be a fixed quantity depending directly on the draught or quantity of air passing through the furnace. Thickness is only one element in the calculation of this surface, the others being the nature of the coal, or the bulk of the pieces of coke, and the area of the grate.

It will naturally be asked what surface of air passages must we have for perfect combustion with a given draught? This, indeed, is the question: and experiment has yet to answer it. Let us consider what data we are in possession of to aid us in solving this important problem.

We will, in the first instance, suppose our fuel to be coke, or carbon, as presenting the simplest case.

Combustion then is the union of carbon with oxygen of the air, Carbon may unite with oxygen (in the furnace) in two proportions, forming two gases—carbonic oxide (C + O), and carbonic acid (C + 2 O). The first is a combustible gas. If we form this gas and it escapes as such up the chimney we lose fuel. Carbonic acid, on the other hand, is carbon saturated with oxygen. Perfect or economical combustion is, therefore, the union of carbon with oxygen in that proportion which constitutes carbonic acid.

Let us suppose that we have so arranged our fire that the surface of coke exposed bears such relation to the quantity of air entering that carbonic acid is formed, what will be the effect of increasing the depth of the fire, or, in other words, of increasing the surface over which the air and gases have to pass? The coke will become heated. But coke heated to redness decomposes carbonic acid, by absorbing the second atom of oxygen (C + 2 O) with C (the excess of coke) becomes 2 (C + O), or carbonic oxyde, which passes up the chimney unconsumed.

The second equivalent of carbon is entirely lost to us. Admitting the increased thickness to be so great that the whole of the carbonic acid is thus converted into carbonic oxide, we shall have obtained no more heat from the combustible used than the half of it would have yielded under a proper arrangement. But this is not all; $\overline{C + 2\ O}$ + C in becoming $\overline{2\ C\ O}$ has doubled its volume; its specific heat has proportionately increased. Heat has been rendered latent in converting the solid carbon into gas, our loss, therefore, is considerably more than 50 per cent of the fuel employed!

Let us now ask what would be the effect of diminishing the thickness of the fire, or surface of the interstices of the coke? The

surface is now too small to saturate the passing oxygen; a portion of the gas will pass through free, or uncombined with the carbon; but this oxygen cannot so pass without becoming heated; cannot become heated without expanding in volume, and, consequently, rendering heat latent; and when we reflect that with each volume of oxygen we have four volumes of nitrogen associated, which undergo a similar physical change, we shall see what a source of loss a diminution of the thickness becomes.

We have not by these considerations ascertained the relation between the surface of coke and the quantity of air passing, but we have discovered a test by which we may know when we have effected it. For

> When the surface is too large carbonic oxide will be found in the gases evolved; when the surface is too small free oxygen will be found in the gases evolved; and when the surface is in due proportion to the air neither gas will be present.

By keeping the draught uniform, and by increasing or diminishing the thickness of fire until the analysis of the gases shows a favourable result, we may ascertain the proper proportion, which will always be true while the circumstances are the same. By varying the circumstances, as draught, area of fire bars, &c., we may probably be able to express our results in a general formula, and thus render what seems now a mere matter of opinion the subject of calculation.

The combustion of coal is less simple. On the gradual application of heat to a substance of organic origin we observe different phenomena, corresponding to different stages of the process, as

1—Change of physical state,

2—Change of chemical nature—decomposition, and, if oxygen be present,

3—Combustion.

With Coal we have, corresponding to these,

1—Fusion (if it be a bituminous coal),

2—Conversion into coke and combustible gas, and

3—Combustion of both of these.

We can now ascertain the conditions required for the perfect combustion of coal. Let us suppose we have a coke fire adjusted for perfect combustion. If we place coals upon it, we shall have fusion and then the formation of gas; but as no free oxygen is present, the whole having been converted into carbonic acid, we shall have no combustion, the combustible gas will either pass up the chimney as such, or its carbon will convert the carbonic acid into carbonic oxide, in either case the whole will be lost to us. We must, therefore, either admit air on the surface of the fire, or we must make our fires so thin that free oxygen will pass through in sufficient quantity to consume this gas. Here then is a fixed point. Above or below we shall have a loss as previously shown. To sum up then—

Fires may be too thick, and too thin.

There is a proper thickness which may be expressed in terms of the draught and area of the grate, and which may be determined by experiment.

DISCUSSION.

Mr. Brough remarked that the subject of the Paper just read was intimately connected with the previous one, and suggested that it would be well to discuss them together.

Mr. Greenwell thought it would be better that the discussion should take place after the papers had been printed, and in the hands of the Members.

Mr. Cox said the subject was very important, and there was much to be said upon it. He agreed that it was, therefore, desirable that the paper should be in the hands of the members previous to the discussion.

Mr. Brough proposed a vote of thanks to Mr. Cox and Mr. Clark, and moved that the papers read be discussed at the next meeting, together with Mr. Fryar's paper.

Mr. Greenwell seconded the proposition, which was agreed to.

The following Paper was then read:—

ON THE OCCURRENCE OF A METALLIFEROUS VEIN OF LEAD, PASSING THROUGH A COAL BED, IN SOUTH WALES.

By Mr. E. ROGERS.

The vein of Lead Ore referred to in this paper, occurs in a seam of Bituminous Coal, in the Pennant series, and is found in the No. 1 Pit, at Abercarn.

The accompanying drawings and specimens illustrate the exact form of the lode, and its mineral character.

The writer does not purpose here to discuss any theory, as to the formation of Mineral Veins, but simply to place on record in the transactions of this Institute some observed facts which may be followed out by others as opportunity offers.

The Lode, as shown on the drawing No. 1, is composed of

Shale and Sandstone, marked ..... A
Calc, Spar, and Iron Pyrites ..... B
Debris of Coal, mixed with Calc, Spar, and Iron Pyrites.. C
Sulphide of Lead ..... D

The Coal immediately in contact with the Lode bears no marks of igneous action. The Shales above and below the Coal are not altered in any way from their ordinary character.

The strike of the Vein or Lode is 20° East of North. (Magtc.)

The dip is North West, and at an angle of 80°, so far as observed; but the vein has not been followed more than three feet above or under the bed of Coal.

The drawing, No. 2, represents an accurate section of the strata sunk through in the No. 3 Pit, at Abercarn, where a Metalliferous vein was found as shown, and was examined carefully as to its form by the writer. The body of this lode was filled principally with Sulphide of Iron (Mundic). The lode itself, as shown, did not extend to the surface, or to a depth of more than twelve yards from its commencement. It is very probable that the lode first described in drawing No. 1 may prove of the same character, and not extend to the surface, or descend to any great depth. If the results of further observations should accord with these facts so closely as to enable us to educe some general law from them, we shall make a step forward in science.

The PRESIDENT said his object was simply to place a remarkable fact on record. He had learned from his friend, the late Sir Henry De la Beche, that such circumstances had occurred and been observed by him in Derbyshire, and it was much to be regretted that no exact record of the details had been preserved. When compared with received theories, it appeared something extraordinary; but probably, attention being once called to it, many other like occurrences were already known, and some friends of science who had made the like observations, would be induced to give their experience, and in the end enable us to educe some general law, the knowledge of which would be of great practical use in mining. It had been attempted to account for the formation of these veins by the action of heat; but this metalliferous vein had been found with bituminous coal on both sides of it; and with shale and sandstone, calc spar, iron pyrites, debris of coal, and sulphuret of lead, all mixed and unchanged by heat. It seemed to prove that metalliferous veins could exist without coming to the surface or extending to a great depth; if so it was a fact not recognised before. The sections before the meeting had been most carefully drawn, and gave exact representation of the mode in which the strata and veins occurred.

Mr. Brough said it was always considered that lead was mainly found in connection with the mountain limestone, which was its natural matrix; or, as it had been called, the "mother of lead." The great question was,—How did the lead come there? Mr. Brough also added, that though mountain limestone was the general abode of "Galena," that lead was also found in much older rocks, as the clay slates of North Wales and the killas of Cornwall.

The President said the vein had not been traced up or down; but, in another bed of coal, which had been worked under it, a metalliferous vein had been found giving iron pyrites, and, as was shewn in section 2, this had been proved to cease above and below the point at which it was discovered, and, there was little doubt, the same law applied to the lead vein, in figure 1.

Mr. Jacob James said that the bed of coal, worked eighty yards below, gave no trace of the lead vein.

The President said that Mr. James was one of the managers of the works when this vein was discovered, and much of the credit of executing these accurate sections, was due to him.

Mr. Brough said that this paper was calculated to set them all thinking; the source of the lode was a mystery. Some day or other, the truth would be elicited, and that would probably be accelerated by correspondence with other similar Institutions.

On the motion of Mr. Greenwell, the thanks of the meeting was voted to the President for his interesting paper.

The proceedings then terminated.

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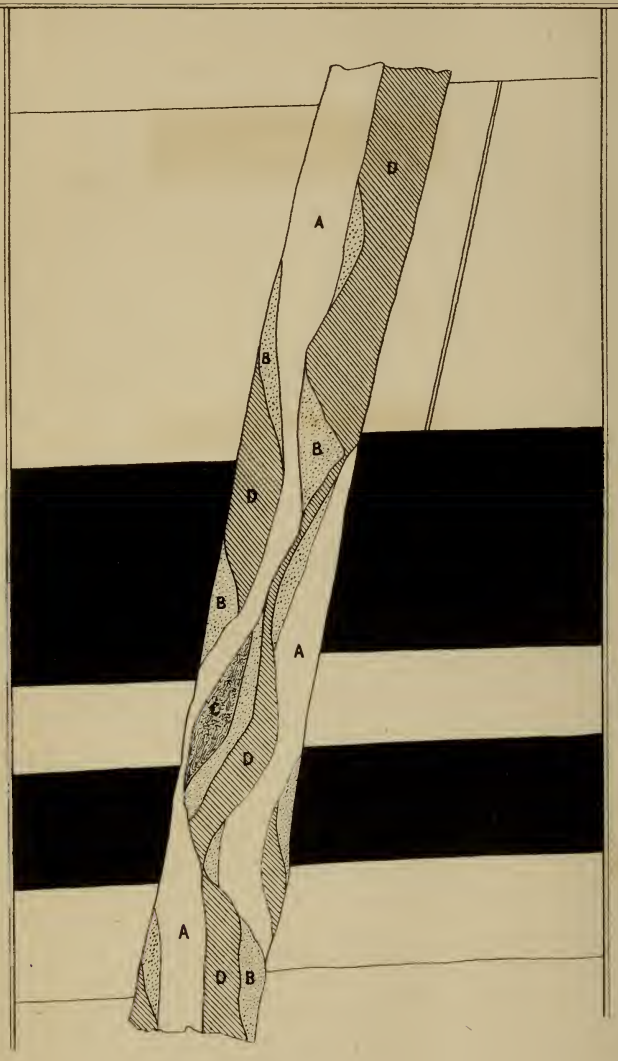
Fig. 1.

VEIN OF LEAD ORE IN COAL.



Hard Shale.

COAL.

Bituminous Shale.

COAL.

Hard Shale.

Scale $\frac{1}{18}$ *th*

A *Shale and Sandstone.*

B *Calc Spar and Iron Pyrites.*

C *Debris of Coal mixed with Calc Spar and Iron Pyrites.*

D *Sulphide of Lead.*

Proceedings S.W.I.E. 1859.

VEIN OF IRON PYRITES IN COAL.

Particulars of Strata	Thickness of each Stratum			Depth from the Surface		
Clod						
Black Shale		.	2			
COAL (Charcoal Seam.)	1	0	9	120	0	0
Fire Clay.	.	.	6			
Siliceous Rock.	4	1	1			
Shale.	.	.	1½			
Siliceous Rock.	.	.	4			
Black Shale.	.	.	4			
COAL.	.	1	1	125	0	3
Shale.	.	.	2			
Siliceous Rock (Very hard.)	5	2	0			
Carboniferous Shale.	2	0	0			
Siliceous Rock (Very hard.)	2	0	10			
Siliceous Rock.	.	1	2			
Clay with balls of Carbonate of Iron.	.	.	9			
Siliceous Rock.	.	1	3			
Shale.	.	1	1			
Clay.	.	1	0			
Siliceous Rock.	2	0	9			
Shale.	.	.	6			
Siliceous Rock.	.	1	0			
Hard dark Shale gradnating into Slate Siliceous Rock.						

Scale 4 yards = 1 inch.

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PROCEEDINGS.

26th April, 1859.

The General Meeting of the Members was held at the Town Hall, Newport, Monmouthshire, on Tuesday, 26th April;

Mr. E. ROGERS, the President, in the Chair.

The Minutes of the January Meeting were read by the Secretary, and confirmed.

The President said that the first business was to nominate office-bearers for the ensuing year. The Council had decided to recommend to the members Mr. W. S. Clark to be the next President, and, when they considered his high position, with regard to the mineral interests of the district, and, also, the ability and zeal he had displayed in furthering the interests of the Institute, he felt assured they would all consider that the Council had made a wise selection. He announced that the following office-bearers, selected

by ballot, would go out of office in July next;—they were all eligible for re-election:—

VICE-PRESIDENTS: Mr. MENELAUS.
" GEORGE MARTIN.

MEMBERS OF COUNCIL: Mr. DAVID ROBERTS.
" JOHN JAMES, Blaina.
" RHYS H. RHYS.
" JOHN COX.

Mr. COX said that at the last meeting of the Council, it had been considered desirable to add to the number of the Council. It was believed that this would be likely to extend the influence of the Institute, in parts of the Principality not now represented; and, it would also tend to strengthen the Institute, by admitting a larger number of members to aid in the management of it. Some discussion had arisen as to the extent to which this increase should be carried;—some members were of opinion that the number should be doubled, but the majority considered that an addition to the Council of six members was the most desirable change. He, therefore, proposed that the number of Councillors, as laid down in rule nine, be altered from twelve to eighteen.

Mr. CHRISTOPHER JAMES seconded the proposition, considering that with the rapid increase in the number of the members, they were not sufficiently represented in the Council.

The PRESIDENT put the question, which was carried unanimously.

The following members were nominated for election as office-bearers, at the next annual meeting:

President :

Mr. W. S. Clark.

Vice-Presidents :

(Two of the number to be elected.)

Mr. William Bedlington.
" Lionel Brough.
" John Cox.
" George Martin.
" William Menelaus.

Council :

(Ten of the number to be elected.)

Mr. Alexander Bassett.
" William Bedlington.
" James Brogden.
" Lionel Brough.
" John Cox.
" Benjamin Dodd.
" George Fisher.
" Mark Fryar.
" G. C. Greenwell.
" George Hamson.
" Frederck Levick, Jun.
" David Llewellin.
" George Martin.
" William Menelaus.
" James Murphy.
" Rhys H. Rhys.
" David Roberts.
" George Smithson.

Treasurer :

Mr. Edward Brigden.

Secretary:

Mr. Edward Williams.

The PRESIDENT said they had now to enter upon the regular business of the meeting. The first subject to which he had to call their attention, was the discussion of the able papers, already read at some of their former meetings. The paper read by Mr. Fryar, at Cardiff, on the Comparative Value of the Fuels, was the first; the second was that read by Mr. Cox, at Merthyr; and the third had been communicated by Mr. Clark, at the same meeting. These papers brought to bear a mass of matter and a great amount of evidence, which, would almost compel them to enter, to a considerable extent, upon the questions lately raised, with regard to the real economy and practical utility of the North of England and South Wales Steam Coals. He was aware that these questions involved some of the most important material and commercial interests of the kingdom. It was not merely of vital interest to the districts more immediately affected, and to the vendors of coals; but, also, to the great Steam Ship Companies of England and the World, that the truth should be ascertained. He therefore trusted they should approach the discussion, in the same spirit with which they would consider any other scientific subject, and not debate it with any rash or intemperate feeling, but consider it calmly and coolly, with the view of ascertaining facts, from which they would draw correct conclusions. In this, as in all other cases, they should keep before their eyes the old national motto of "*The truth against the World.*" He hoped that in adopting the strict line of enquiry after truth, and divesting themselves of all prejudice, there would not be a word uttered that could possibly be construed into a desire to wrong the North Country—they would thus maintain the true dignity of a scientific Institution,—and not look at the subject merely from a little local point of view. At the same time he begged to state, that they would be glad to hear the opinions of any gentleman present, not being a member, who might be desirous of making any remark on the subject before them.

Mr. COX said that he felt some diffidence in commencing the discussion,—more especially as one of the papers read had been his own; but he should like to say a few words in explanation of his

motives for writing it, and in extension of its views. As they were already aware, it was found impossible to discuss the very able paper contributed by Mr. Fryar, at the time it was read at Cardiff. On reading that paper, it appeared to him, that he could not reconcile some of the doctrines laid down with the conclusions arrived at.—The writer professed to give the palm to the Welsh coals, while, according to the view which he (Mr Cox) took of the doctrines, they would have given the palm to the coals of the North Country. He would just read a few lines,—they appeared in the first paragraph, and as they were not very clearly expressed, he might have misunderstood their meaning,—but, if so, he should still have something to say. "The fuels are those substances "in nature which have been produced by the combination of car- "bon, oxygen, and hydrogen; and their relative value very much "depends upon the proportions in which carbon and hydrogen enter "into their composition, while their entire consumption depends upon "the presence of oxygen, either as a natural component or as sup- "plied by the atmosphere. Whatever may be said by experimen- "talists respecting the results of their experiments with fuels, "a common sense investigation of the subject, aided by a fair "amount of scientific knowledge, will shew that unless these sub- "stances are naturally combined in the fuel, or can be brought "together with ease and without expense, it must be comparatively "valueless." As he understood it, this passage meant to convey that without oxygen the fuel would be valueless;—and if this was the meaning, he, at once, took exception to it, and would assert that one of the strongest reasons for the great superiority of the South Wales coals was the almost total absence of oxygen; and, for the inferiority of the Newcastle coal, the presence of an extraordinary large amount of it. Even if Mr. Fryar did not mean to include the oxygen, he could not see why the union of hydrogen and carbon was necessary in a fuel; but he could understand that as hydrogen produced a much larger amount of heat in combustion than carbon, the larger quantity the coal contained of it the better, provided that it and the carbon were not organically united. Where this was the case, as it was in all bituminous coals, it was distilled

off with a portion of the carbon so united with it in the shape of carburetted hydrogen, the perfect combustion of which, at no time easy to effect, was then rendered still more difficult by the presence of the vapour of water evolved by the combustion of hydrogen, and the vapourization of hygroscopic water. There was another paragraph in Mr. Fryar's paper with which he should not have troubled the meeting but that it appeared to be intended to bear on this subject, and imply some mysterious effect to the presence of oxygen. He stated—"But as 'the greater the proportion of hy-"'drogen contained in a fuel to that of oxygen, the more numerous "'are the combinations of carbon produced;' it follows that in the "bituminous class of coals, which we have noticed as containing "4.08 per cent. more oxygen than the semi-bituminous, the com-"binations of hydrogen and oxygen forming vapours of water will "be much more numerous than in the latter." If the proposition was intelligible he could find no evidence of its truth; the conclusion sought to be drawn from it appeared to him to be inconsequent; and what light it was intended to throw upon the subject he was totally at a loss to comprehend. It was not the difference in the quantity of hydrogen that made a coal bituminous or otherwise; as might be seen by comparing the analysis of some of the Welsh coals, the Ebbw Vale Elled for instance, and the Hartley; which shews a difference of only .15 per cent.: it is the fact of its existing in organic union with the carbon, and thus necessitating its evolution during combustion, in connexion with it as carburetted hydrogen. This is not the case with the Welsh smokeless coals in which the organic union has been severed, and the hydrogen coming off not united with the carbon presents itself in the fittest shape for combustion. He wished, however, emphatically to urge that although the presence of smoke was an evidence of imperfect, its absence was no proof of perfect combustion; to ordinary eyes it appeared so, and it was so generally believed, that even the Government Engineers, Messrs. Miller and Tamplin, while they applied Mr. Williams's smoke consuming apparatus to the combustion of the Newcastle, carefully closed the openings for the admission of air when using the Welsh coals; yet they took credit for having ap-

plied to both an impartial and equal test. He could not venture to suppose that they had done so strange an act wilfully, and he could only attribute it to ignorance of the principles of chemistry which governed the combinations of carbon and oxygen. In every instance they threw the cinders on the fire and state the effect to have been "the preventing the formation of smoke, as the carbon "appeared to take up the carburet of the coal in combination and "form carbonic acid gas, which is the result of perfect combustion." Without discussing the extraordinary chemical information contained in this sentence he would merely state a fact well known to practical men, that although red hot cinders on the top of bituminous coal in combustion does reduce the evolution of smoke by effecting a separation of the carbon and hydrogen, its effect on the products of carbon is that even when perfect combustion or the formation of carbonic acid has taken place on the bars, it would absorb one portion of the oxygen and convert it into carbonic oxide, so that if no air were admitted over the fire, three-fourths of the fuel would pass unconsumed up the chimney. This was no unsupported theory; it was a fact admitted by all chemists who had investigated the laws of combustion, to the truth of which he could add the testimony of experience; as having passed days, and often nights, for weeks together on the footboard of the Locomotive, he had often seen the flame of carbonic oxyde so generated burning some feet high at the chimney top. Engine drivers, while burning coke only, very early practised the admission of air over the fire by slightly opening the fire doors. Some Locomotive Engineers had improved on this by making holes in the doors, and he warned the Welsh coal proprietors that they must not supinely rely that their coal was properly burnt because it emitted no smoke. He would not detain the meeting longer, as he should have to reply to any point that might arise during the discussion.

Mr. Greenwell said that he simply rose to remark that it appeared to him scarcely right, to comment so strongly on the report of the government engineers&others, without further evidence. With regard to the absence of oxygen in the Welsh coals, and its

presence in those of the North of England, to which an inferiority in the latter was attributed, it was a question as yet undetermined; and, therefore, ought not to be made the subject of such pointed remarks.

The PRESIDENT was thankful for the observation,—they could not be too cautious in treating undetermined matters in science. He would endeavour to deal with it in summing up.

Mr. MENELAUS thought that Mr. Cox was wrong in imputing ignorance to the government engineers. It was said to be the great merit of the Welsh coals that they required no peculiar kind of grate,—that they only required ordinary grates and ordinary management; and, in this respect, he believed that they were the best in the kingdom. It was said by the advocates of the North of England coals that with special apparatus and a certain amount of care, they would rival the Welsh coals. The government engineers had, therefore, applied that test to the Newcastle coals, and had taken the grate as they found it—testing them against Welsh coals burned in the ordinary manner. He believed that all the North Country people said was, that they had found a grate which would enable their coals to do a larger amount of work than the Welsh,—and it might turn out to be so. Let them, therefore, if possible, improve their fire-grates, and use every means possible to improve the combustion of their own coal, and to get a still greater amount of work from it. It was not right, he thought, to attribute ignorance or unfair feeling to the government engineers under this circumstance.

Mr. MARK FRYAR said that he would merely remark upon some points alluded to by Mr. Cox, though he should be glad to listen to a discussion,—especially on the improvement of combustion by mechanical means. Mr. Cox had commenced his observations by referring to a passage in the paper contributed by him (Mr. Fryar), in which he had described carbon, hydrogen, and oxygen as combined in fuels. He should suppose that Mr. Cox was not prepared to deny that these were the three elementary substances that entered into the composition of fuels,—and that

combustion depended on the supply of oxygen, either from the atmosphere or from the coal itself. He had simply desired to intimate that oxygen might be supplied from the coal; he was not prepared to say that free oxygen was to be found in all coke or coal,—he did not make any assertion to the effect that all coals must contain oxygen; nor did he intend to lay any stress on the matter. The next point to which he wished to refer was a paragraph in the paper read by Mr. Cox at the last meeting, viz.:— "Whatever may be the cause the fact is unquestioned, that the "union of oxygen with most, if not all other bodies produce heat; "and though we speak of such bodies as combustibles, and reckon "their value by the heat given out by what we denominate their "combustion, it is the generally received opinion, that the heat is "derived from the oxygen and not from the body uniting with it; and "we suppose, therefore, that the heat created should be in proportion "to the quantity of oxygen with which the so-called combustible is "capable of uniting." He could not understand how oxygen could be a heating power; neither could he comprehend how carbon could be a heating power without combination. Heat was the result of combination; but he did not know how to speak of either, apart from its combinations. Mr. Cox also said—"That no loss of "heat in its combustion," speaking of hydrogen, "has to be feared "on account of the greater capacity for absorbing heat of the pro- "duct of its combustion (vapour of water), over carbonic acid gas "(the product of the combustion of carbon), is evident from the "results of the experiments of the eminent chemists who have de- "voted themselves to the investigation of this subject, as, whether "in the shape of hydrogen unmixed with carbon, of marsh gas, or "of carburetted hydrogen, the result of its evaporating power is in "excess of what theory would have anticipated (as compared with "the heat produced by the combustion of carbon), thus shewing "that there is no deficiency we would seek to account for, by attri- "buting it to this cause. This theory, as far as hydrogen is con- "cerned, is more than borne out by the experiments of chemists, as "it has been found to create about 4.5 times as much heat as car- "bon, which may be accounted for by supposing that some large

"allowance should be made from the results of these experiments "for the heat required to volatilize the solid hydrogen as it exists in "coal; the experiments having been conducted with hydrogen in "the shape of gas, as against solid carbon, so that the comparative "deficiency in the heating power of carbon was to be attributed to "the greater heat absorbed in its volatilization." He did not quite understand what Mr. Cox meant in the paragraph—he had, therefore, just mentioned it to call attention to it, as he fancied it was intended as an objection to a portion of his paper.

Mr. Cox said that the paragraph just read had no reference to Mr. Fryar's paper,—he had simply intended to insist that as a solid body must absorb a certain amount of heat before it could be converted into vapour; the hydrogen (which existed in a solid state in coal) must take up that amount before it could assume the shape in which it existed when experimented on.

Mr. FRYAR resumed: He wished to leave the general discussion to other members better able to carry it on than he was; but there was another point in Mr. Cox's paper, that he desired to notice. It was known that vapour of water had a greater capacity for heat than any gas, and the only point to be settled here, was, whether vapour of water was slow in absorbing heat if let into the fire box. All the heat ought to go towards raising steam. It must, therefore, diminish the value of any kind of fuel if it contained vapour of water, for it must absorb a portion of heat. All must agree that where vapour of water was present in any quantity, as the result of combustion, in the fire box or under the boiler, it must absorb a certain amount of heat. Quoting from "Brande's Manual of Chemistry," he said, that where the capacity of water was represented by the unit 1, carbonic acid would be represented by 0.22,—hydrogen by 3.29,—oxygen by 0.23; or, the capacity of water would be greater by five times than that of carbonic acid. On referring to his own paper, he found that the quantity of hydrogen and oxygen in bituminous coals, amounted to about the same proportions as they existed in water. He did not mean to say, of course, that they existed separately in those proportions, but

in combination with other matters;—and it might be, that, during combustion, they combined to form vapour of water, and thus absorbed a great amount of heat that might otherwise have gone to raise steam. There were two or three other points brought before them, but he should leave the matter there, feeling very anxious to hear discussed, the question, whether there was not danger that the introduction of vapour of water into the fire box, would absorb heat that should be employed in raising steam.

Mr. W. S. Clark said that in theoretic heating quality, the Welsh coals and those of the North of England came very near each other. The quantity of hydrogen in the North Country coal was large. There was more carbon in the coal of South Wales. In ordinary analysis they came very near together. The practical point for discussion was their treatment under the boiler. It was a mechanical question rather than a chemical one.

Mr. Brough enquired whether he might be allowed to ask Mr. Cox what he meant by an "organic union?"

Mr. Cox said that he meant that the substances forming coal had passed through vegetable life. As products of their distillation they had carburetted hydrogen. The hydrogen was not separated from the carbon, but existed in combination. In the Welsh coals they found but very little oxygen.

Mr. Brough enquired whether he wished to infer that the hydrogen existed in a solid state? In that case there must be a considerable loss of heat. He objected to the theory altogether, that of chemical combination; hydrogen, it is known, existed in coal in a highly concentrated form. As fire-damp it was very expansive, and capable of exercising tremendous force,—an instance was known where 11 tons of coal had been forced out of the side of a vein, by an expanding volume of hydrogen.—That was a fine proof that it was not there in a solid state.

Mr. S. B. Rogers said that combinations of peculiar substances became organic, by the application of some other power not at present known. In no case would organic union exist, either by the application of chemical or mechanical means, without the intro-

duction of that third power, which altered their condition altogether, and which approached to life. He would not say further than that a combination, without having passed through some kind of life, must be either chemical or mechanical.

Mr. Brough had one further observation to make, which would rather support Mr. Fryar's views. The amount of heat evolved in the process of combustion was in exact proportion to the quantity of Oxygen absorbed from the atmosphere; therefore, with regard to any fuel, whether Powell's Welsh, or Hartley Newcastle coal, if the proportion of carbon therein contained, be multiplied by 2.66, and the hydrogen by 8, the relative heating powers will be manifest as far as calculation is concerned. But the North of England coals are all more or less bituminous, and each atom or pound of hydrogen requiring for perfect combustion eight times its weight of oxygen, as previously stated, it was obvious that those coals which contained the largest amount of hydrogen, would more rapidly than any other liberate from the atmosphere immense and disproportionate volumes of a gas (nitrogen) that could not in any way support combustion; and which, in its passage through restricted flues and up the stack, was found to deprive the boiler of a large amount of heat by the well known process of convection. For every volume of oxygen taken up in combustion nearly four volumes of pernicious azote was set free from the atmosphere, to the great reduction of realized caloric. The enormous quantity of free nitrogen thus thrown suddenly under and around the boiler could not but exercise a damaging action on the heat already generated, and thus, probably, would show, that as far as chemical calculation goes, the difference in heating power between the two classes of coal was in a great measure counterbalanced. Nitrogen, it was known, destroyed combustion, and on this ground especially the Welsh coals should be superior to those of Northumberland and Durham; was it not a chemical fact?

Mr. Cox said that was a position he had not taken into consideration.

Mr. Brough enquired whether it was not a position worthy of the most careful consideration, as it was a great evil connected with the combustion of coals, and from which the coals of South Wales were freer than any other. The presence of azote tended to lower temperature.—Bituminous coals with 8 times its weight of oxygen for one of hydrogen, must liberate immense volumes of nitrogen.

Mr. Roper thought that there was much in both papers worthy of their serious consideration,—but he would endeavour to point out some few statements that he thought were open to objection; at the same time, he agreed with the preceding speakers on the importance of the subject brought before them, and the value of the papers introducing it. In the first place Mr. Fryar states "that unless these substances,"—carbon, hydrogen, and oxygen,—"are naturally combined in the fuel, or can be brought together "with ease and without expense, it must be comparatively worth-"less." This passage was liable to lead to error. But he could scarcely imagine Mr. Fryar intending to assert that it was necessary for the combustion of a fuel, that it should contain oxygen, while it existed in almost infinite quantities in the atmosphere, ready to support combustion whenever it was required. If this had been Mr. Fryar's intention, its fallacy had been pointed out by Mr. Cox, who had shown that the oxygen in the fuel was useless, and in some cases prejudicial. He would go still further and assert that the presence of oxygen in fuel, under any circumstances that he could imagine, was unprofitable.—For the producer had to raise—and the consumer to buy—a proportion of an element which did not in any way improve the quality of the fuel, but, rather the contrary; while the circumambient atmosphere supplied the same element, in quantities far more than sufficient for all the wants of man. Hitherto the discussion had turned entirely on questions relating to coal; but, there was one fuel mentioned in Mr. Fryar's paper to which he would call their attention, viz.:—Peat. As far as he was acquainted with this district, peat did not exist in any large quantities, as it did in other parts of the kingdom, in Scotland, Ireland, and many Continental countries. Though this fuel

had hitherto heen greatly neglected, he considered it to be very valuable; and an extension of its use to metallurgical operations and manufactures would greatly enhance the value, and increase the riches and commercial importance of our sister countries—Scotland and Ireland. Peat had been used in England, France, Germany, and Russia, for the manufacture of iron, and was, he believed, still employed for that purpose in the two latter countries. It might possibly be interesting to some of the members to know that peat had been used for the smelting of Hematite iron ore, in Lancashire, though it had been long abandoned for that purpose.—Why, he did not know. He would quote a passage from the 3rd edition of the "Encyclopædia Britanica," vol 14, page 77, to prove this statement. —"Although it may appear incredible (says M. Magellan), it is "nevertheless a real fact, that in England pit turf is advantageously "employed in Lancashire to smelt the iron ore of that county. "Mr Wilkinson, brother-in-law to Dr. Priestly, makes use of pit turf in his large furnaces." This use of peat by Mr. Wilkinson occurred about 70 years ago, at a furnace near Castle Head, about 12 miles from Ulverstone, in North Lancashire. If his memory served him right, Swedenborg also refers to the same use of peat in that district, though it was probably at a much earlier date than that of Mr. Wilkinson's trials. Peat had also been used in the welding and working of iron; and it had some peculiar properties which rendered it well adapted for these purposes. It had also been used in Smiths' fires with advantage; and for tempering steel. The chief objection that had been made against the use of peat, was that it contained a great and variable quantity of ash.—But there really seemed, from the valuable series of analysis of Irish peat made by Sir Robert Kane, to be little or no foundation for such an objection. Mr. Fryar assumes to have given Sir Robert's figures, when he states that the average per centage of ash in 27 varieties of peat from the Bog of Allen, is 3.7;—but on examining these analysis he found the mean per centage to be 2.596, —constituting a material difference. Amongst these samples there were several that contained a smaller per centage of ash, than the best specimens of coal that Britain can produce. In three unpub-

lished analysis of the ash of peat by Dr. Muspratt,—two of which were of Irish samples, from the neighbourhood of Sligo, and the other of peat from near Ulverstone,—the following results were obtained:

Irish peat.....Upper bed...per centage of ash...1.054
" " .....Lower bed. " " ...1.428
Lancashire peat ..... " " ...1.568

Another objection had been raised to the use of peat which appeared to be unfounded, viz.:—that its ash contained such a proportion of phosphates and sulphates, as to injuriously effect the quality of the iron to be made by it. An examination of the analysis previously alluded to would be, he thought, sufficient to convince the enlightened metallurgist, that no such obstacle exists; and that, so far as can be judged from chemical analysis, there was no doubt that peat would make as good iron as coal,—and, in his opinion, considerably better. He thought it was possible to make compressed peat charcoal for 10s. per ton, or even less; and that such fuel would withstand a strong blast, and furnish iron intermediate in quality to cold blast coke and cold blast charcoal pig;—and at about the same cost as that of the former. He had been induced to make these remarks with the view of assisting in the spread of information regarding one of the most neglected sources of wealth in the three kingdoms. He would now make a few observations on the steam coal question. A good deal had been said about the respective calorific values of the North Country and South Welsh coals. He had calculated the values of these coals, taking the most recent determinations of the calorific value of carbon and hydrogen, and the mean of ten analysis of Newcastle and ten of Cardiff coals,—as given by Mr. Fryar,—as data for this purpose; the result was that the Cardiff coal had a calorific value one-twenty-fifth higher than that of the Newcastle coal. The calorific value of Cardiff coal

As per average of 10 analysis being 8446
And that of Newcastle coal..... 8109

It would therefore appear, that as far as theoretical calorific value was concerned, there was very little difference between the two

kinds of steam coal.—But it should be observed that there was considerable difference in the quantity of water produced by their combustion. In the case of the mean analysis of the Cardiff coal, the weight of water produced by combustion or existing as such in the coal was 1.90 per cent; while in the case of the Newcastle coal, the weight, per cent., was 6.49,—or nearly $3\frac{1}{2}$ times as much; and, as the specific heat of vapour of water was nearly $4\frac{1}{2}$ times that of carbonic acid, there must of necessity be a considerable dimunition of the theoretical calorific value of the Newcastle coal, which dimunition accounted in great measure for the practical disparity of heating power existing between them. Mr. Cox had stated in his paper—"That it is the "generally received opinion that the heat (given out by the union "of oxygen with combustibles), is derived from the oxygen, and "not from the body uniting with it; and we suppose, therefore, that "the heat created should be in proportion to the quantity of oxygen "with which the so-called combustible is capable of uniting." He must dissent from the assertions in this passage. It could not be positively affirmed in any case that either of two elements entering into combustion produced the heat really resulting from such combustion. Combustion was, chemically speaking, used in a much larger sense than that here given to it, and the union of hydrogen and chlorine—or of iodine and phosphorus—which produced heat and light—was as much combustion as any union in which oxygen played a part. The latter part of the paragraph was also erroneous. It had been put forward as an hypothesis by Welter, and at the time he propounded it the determinations of the calorific value of many of the elements seemed to confirm the accuracy of this view, but more recent experiments had convinced philosophers of its inaccuracy, and he would give the results of their experiments in one or two of the cases bearing most on this subject, to show that the basis of Mr. Cox's views were erroneous. Thus—

				Units of Heat.
1 part of oxygen uniting with hydrogen gave				4226.
1	ditto	ditto	carbon	2962.
1	ditto	ditto	sulphur	1500.

Mr. Cox's views of combustion had, therefore, led him to make his

calculations as if hydrogen had only 3 times the calorific value of carbon, while in reality it had about 4½ times. He would also notice another error Mr. Cox had fallen into. The error was contained in the following passage—"It would make no difference as to the amount of "heating power it would neutralize, whether it (oxygen) "united with the hydrogen or carbon." Now it was only necessary to take analysis of coal, and calculate the heating power given out by the union of its oxygen with its hydrogen or carbon respectively, to show that this was incorrect. Suppose we have a coal constituted as follows—Carbon 80 per cent., hydrogen 4 per cent., oxygen 10 per cent., ash 6 per cent.; then 10 per cent. of oxygen would neutralize, or combine, with 3.75 per cent. of carbon; or 1.25 per cent. of hydrogen, and 3.75 per cent. of carbon, would produce 29,625 units of heat; and 1.25 per cent. of hydrogen, 42,500 units of heat—leaving 12,875 units of heat in favour of the union of the oxygen with the hydrogen over that of its union with carbon. He did not think there were any other points to which it would be necessary for him to draw their attention, but would leave the discussion in the hands of those whose practical experience enabled them to deal with this important subject in a conclusive manner.

Mr. Greenwell thought that the matter had been very fairly treated, but wished to ask Mr. Cox whether he intended to state that the alleged superiority of South Wales coal over that of the North of England, was due to the absence of oxygen?

Mr. Cox said that the expression he had used was "in a great measure;" he therefore, had not attributed it solely to that cause. In his paper he had pointed out the superiority of Welsh coal as due to many other things. He believed that Welsh coal was superior, and, in discussing the combustion of coals, it was impossible to do so without mentioning it. Mr. Menelaus had found fault with him for attributing blame to the government engineers, for the mode in which they had carried on the experiments, and said that they were right in trying the North of England coals by the best way they could find, while they were trying the coals of South Wales in the common way.—He could not understand that.

The great question at issue was one of economy, and he could not see that the Government Engineers had tested this at all by the mode they had adopted, as every known means had been applied to effect the perfect combustion of the Newcastle coals while the Welsh were treated in the ordinary way. Treated in this way with the furnace doors closed, unless the firing were most carefully conducted, three-fourths of the heating power might pass up the chimney. Mr. Menelaus blamed him for imputing ignorance to the government engineers, but, he could not on the other hand, impute to them bad motives; he must suppose, therefore, that they were ignorant of the fact. There were many facts of which highly scientific men were ignorant, and to say that they were not aware of any fact in science, could not be deemed offensive. There were many practical men present who could bear witness that, in such a case, a great proportion of heat would go up the chimney. The North Country coal in burning cakes on the fire, preventing the passage of air through it, and plainly shewed the necessity of providing it elsewhere; while the Welsh coal, as the peculiar union of carbon and hydrogen called bitumen did not exist in it, lay more open on the fire, and permitted a greater amount of air to pass through it, if the fire were not too thick; still it was not enough for perfect combustion. Mr. Fryar in speaking of the action of vapour of water, had quoted to them a portion of Mr. Cox's paper, to which he attributed a meaning different to that which it was intended to convey. Mr. Fryar would have them believe that he (Mr. Cox) meant to deny the greater capacity of the vapour of water for absorbing heat, whereas he merely said that it did not require to be taken into calculation, because the data on which our calculations are founded, were substantiated by the results of experiments, which, in themselves, necessarily contained whatever allowance would be required to be made for this; as the hydrogen consumed in the experiments would necessarily have produced a similar proportionate quantity of vapour of water as would hydrogen contained in coal. Mr Fryar had put forth a cloud of figures which it was impossible for him then to follow. He should next reply to Mr. Brough's question with regard to organic union. He held that

there must be that kind of power spoken of by Mr. Rogers to cause the union of carbon and hydrogen; the power he considered to be organic, and that union organic union. That state of union was separated by heat. It had been so separated by the internal heat of the earth in the semi-anthracites, which constituted the distinction between them and bituminous coals. He should next allude to Mr. Roper's remarks. Mr. Roper said he had not allowed sufficient for the heating power of hydrogen as compared with carbon. He did not deny this, but if Mr. Roper referred to his (Mr. Cox's) paper he would see that he had taken the same data as had been used by Messrs. De la Beche and Playfair in order not to complicate the question, while at the same time he had expressly stated his cognizance of the fact that eminent chemists gave to hydrogen a much higher power. He thought he had now replied to all the arguments adduced.

Mr. Brough said that he wished to say one word. Mr. Fryar had stated with great truth, that vapour of water carried away with it a certain amount of heat—represented as unit. It was a curious fact that the coals of the North of England frequently contained the two remarkable elements of oxygen and hydrogen, in very much about the same proportions in which they constitute water. It would seem as if nature had saturated these coals with oxygen and hydrogen, in the proportions of which water consisted; and it was another proof that Welsh coals must have a greater capacity for raising steam, than the coals holding these elements in that proportion. He believed that the specific heat of vapour of water was 0.8470; the other gasses, on an average, 0.2669. It was therefore evident that a good deal of heat must be lost under the boiler,—that was the object to ascertain. It had recently been made more manifest than ever, that the coal of the North of England contained elements which militated against its useful powers.

Mr. Cox said that it was true the large quantity of oxygen in the Newcastle coals appeared generally to be neutralized by a proportionate increase of hydrogen. This was the case with the average of 10 samples taken by Mr. Fryar. He wished to do as much

justice to the Newcastle coals as he could, but he did not think it would alter their position; there was a dimunition in the quantity of carbon proportioned to the excess of the other constituents, and the excess of hydrogen being neutralized the total heating power was reduced.

Mr. Brough held that certain elements rendered the loss of fuel greater under the boiler.—There were other reasons besides those of a chemical nature. The mechanical structure of the coal was of immense importance,—some kinds could be better handled on the fire bars, and were more easy for the stokers to manage. That was a point that ought to be discussed, even as much as its chemical composition. The mode of stoking was of very great importance. He had made many voyages in different parts of the world, and had paid much attention to the mode adopted on board ocean steamers. The stokers were generally very ignorant, and often mere Irish labourers; and they were not the men to make the most of coals. They should be a class of skilled workmen.

The President remarked that as the discussion was of so much importance, ample time had been given for consideration of the papers previously read, by putting it off for two meetings. It was a subject that required time and research to enable them to discuss it properly. The papers now discussed differed very little as to the general theory and laws of combustion, but each of the authors had taken the view of the subject from his standpoint,—and naturally regarded that most, which had most interested him. The discussion of subjects like this in detail, from different points of view, is one of the objects of this Institute, and a most effective method of leading to improvement and further discoveries. Mr. Fryar, whose paper introduced the subject, had given interesting information on the comparative value of fuels; and had more especially directed attention to coal,—and the difference in value and the mode of combustion of the several varieties of coal, graduating from highly bituminous to anthracite. He had called attention to the statement that bituminous coals containing a large proportion of oxygen, formed more vapour of water and other

compounds, than was formed in semi-anthracite coal. Mr. Fryar had also reminded them that the smoke issuing from the burning of the bituminous coal was mostly steam coloured by floating particles of unburned carbon: and from this and other points you have heard stated and discussed, he concludes "that the relative heating "power of coal is intimately connected with the proportion which "the combinations of carbon sustain in the products of its com- "bustion." He also refers to the prevention of smoke from bituminous coal by admitting air into the furnace; but at the same time shews the great difficulty in effecting this practically.—Mr. Cox directs our attention to the heat given out in the combination of oxygen with hydrogen, and of oxygen with carbonic oxide. He then minutely discusses the effect of hygroscopic water in different coals, and maintains that in estimating the theoretic value of coals, the amount of heat, which the hygroscopic water is assumed to neutralize, should be deducted from the theoretical value of the coals.—Mr. Clark in his communication, describes the several methods of burning coal under steam boilers, and concludes that we must either admit air on the surface of the fire, or we must make our fires so thin that the free oxygen will pass through in sufficient quantity to consume the carbonic oxide. All of these papers in some shape had brought before the Institute the question of the comparative value of the North of England and Welsh steam coals; and the discussion to day also had shewn that to ventilate this subject was, to a great extent, the aim of the writers. The theorem maintained by Mr. Fryar he has been able to establish, viz.: "That the heating power of coal is intimately connected with the "proportion which the combinations of carbon sustain in the pro- "ducts of its combustion."—The remarks as to the consumption of the bituminous coal we will refer to hereafter. The next paper, so far as it comprises a review only of the first, does not differ materially; but it takes up also new ground. It is stated that in estimating the theoretic value of coals, the amount of heat which the hygroscopic water is assumed to neutralize, should be deducted from the theoretic value of the coals; the argument for this point is

not sustained by the result of any practical experiments, and must be taken, at present, as hypothetical only.—No doubt can exist, that the value of the coal is reduced in the same ratio as the weight of hygroscopic water in it; but the effect of that water to waste heat further in combustion, by neutralizing the calorific effect of the fuel, is still an open question. An opinion prevails amongst practical men, that some advantage is gained by using fuel in furnaces with long flues, in a slightly moist state; and that the ashpits should be kept so wet that steam may be generated, by radiated heat given through the fire bars, and then passed through the fire;—these practical opinions are supported by high scientific authorities. Many persons assert that heat is actually gained by the use of water: this, however, cannot possibly be so; it may be, however, that the radiated heat which would be lost, is utilized in producing steam from the ashpit, and so adds a little to the effect of the coal. This view is well explained by Gmelin in his "Handbook of Chemistry," vol. 2, page 88, he states that "We often meet with the "erroneous assertion, that the heat which may be obtained by the "combustion of charcoal is increased by the addition of water. Those "who make this assertion forget, that when the oxygen entered into "combination with the hydrogen to form water, a certain quantity "of heat was developed, which must be deducted now that the "water is decomposed by the carbon. The quantity of heat "evolved is the same, whether carbonic acid is formed from the "combination of carbon and oxygen, or carbonic acid and water "from carbon, oxygen, and water;—excepting that in the latter "case, an additional quantity of heat is rendered latent in the for-"mation of vapour of water. The access of water lessens the "glow-fire, but produces a greater quantity of flame, in consequence "of the formation of carbonic oxide and hydrogen gasses." It has been also maintained, that the coke or carbon only in all bituminous coals is the representative of its practical value; that in practice the hydrogen is of no service, as its heat is so diffused as to produce no material effect: this is a very important subject, and deserving of further enquiry. Some time since, Mr. Joseph Parkes made some able and accurate experiments on this subject, as also Mr.

Apsley Pellatt, (for details see several papers in the "Trans. of Civil Engineers London, cir. 1850,) these gentlemen found that for their purposes "one chaldron of coke weighing 13 or 14 cwt., per- "formed the same heating duty as one ton, or 20 cwt of Newcastle "small coals." In 1857, Mr. Apsley Pellatt again called the attention of the Society of Arts to this subject, (Journ. Soc. Arts, vol. 6, No. 263,) and reiterated the same statement, and proved his case by practical experiments on a large scale. In the discussion Mr. Frederick Pellatt said,—"In a question of this kind facts were bet- "ter than opinions. In his manufactory for many years they used "small coal in the melting of glass, the consumption being about "30 tons per week. Contrary to the prejudices of himself and his "workmen, he was induced to try coke. The stokers asserted that "it was impossible to get sufficient flame from it to do the work. "However, the experiment was made, and the result of a trial of "eighteen months was, that they practically got from 13 cwt. of "coke, the same amount of work as was obtained from 21 cwt. of "coal.—That was a practical fact, within his own experience." It is well known in practice, that moisture in coke creates flame, and diminishes its power to give intense heat in the "glow-fire." All the cases in which coke has been found equivalent in effect to the total weight of coal from which it was produced, seem to have been where intense local heat was required; and where there was no length of flues to render flame effective:—and, *vice versa*, where bituminous and damp coal is found effective; for instance, in the Cornish boiler, where the flue is about 100 feet in length. From these data and other experimental researches we are led to the conclusion:—That as we decompose or utilize coal at present, the carbon only is of effective value where intense local heat is required, as for glass melting pots, and furnaces with short flues and rapid draft where the flame cannot be used; also, that the effective value of a limited proportion of the moisture in the coal seems to depend upon the length of the flues, and time allowed for combustion; enabling the heat of the flame to be used. In this latter case, the heat taken up in the "glow-fire," is given out again in the flame.

We now come to the comparative value of the North of England and the Welsh steam coal. This subject is of such immediate importance to the steam marine of this country and of the world, as to demand a careful review. This Institute has, as a body, so far dealt with the subject, not as party contest, but with sincere desire to elicit the truth; let us always remember our national challenge, "Y gwir yn erbyn y Byd" ("The truth against the World,") and carefully avoid, in these investigations, being led astray by our own prejudices or feelings. All the researches on this subject, the results of which are as yet known, and may be useful to us, can be shortly classed in series, thus*—

1st.—The reports "On the coals suited to the steam navy by Sir "Henry De la Beche and Dr. Lyon Playfair; presented to "both Houses of Parliament by command of Her Majesty."
London: W. Clowes and Sons,—1848 to 1851.

2nd.—The Newcastle-upon-Tyne Steam Collieries Association Reports "On the use of the steam coals of the Hartley Dis- "trict of Northumberland in marine boilers, by W. G. Arm- "strong, J. A. Longridge, and Thos. Richardson."
Newcastle-on-Tyne: A. Reid.—1858.

3rd.—"Report on the relative theoretical evaporative power of "Welsh and Newcastle coals, with tables shewing the results "of experiments, by W. A. Millar, A. W. Hoffman, and E. "Frankland."—London: 1858.

4th.—The "Reports of Messrs. Miller & Taplin on the Evapora- "tive power and economic value of Hartley coals, and similar "report by the same Gentlemen on the properties of Welsh "steam coal, presented to the Board of Admiralty," 1859.

5th.—The actual experience of the principal Ocean-going Steamers, where economy in weight of fuel, and great speed, are absolutely necessary for their success and existence.

The first series of these reports was commenced in March, 1846, and completed about April, 1851; this enquiry was undertaken at

* The reports of the French and American Governments are omitted, as not strictly of importance in this enquiry.

the suggestion of the late Joseph Hume, M.P., whose keen penetration seems at this early period to have fully estimated its national importance. The reports by Sir H. De la Beche and Dr. Playfair commence by giving the principles and data on which they based their experiments; the results of their experiments as to the theoretical value of the coals they analysed have never been disputed. To know these truths is of great importance to the Engineer; it gives him the knowledge of the point that separates the possible from the impossible, and he knows the bounds to work in; it is now his duty to shew us how he can deal with a substance the true value of which he knows; but, as its physical condition varies, he must adopt right mechanical means to eliminate the power shewn to be at his disposal. The formulæ by which the theoretic and true value of coals are calculated are not difficult to apply, and may be interesting and very useful to many; we will collect and explain them here. We take much of this from the able reports before us. The experimental data from which the results are deduced we will first explain. Dulong has shewn that one part by weight of carbon, burning with atmospheric air into carbonic acid, heats 13,268 parts of water, 1° Fahr., or one part of hydrogen, 62,470 parts of water, 1° Fahr.* Regnault has shewn that the co-efficient for the latent heat of steam at 212° is 965.7°. Joule has shewn that one pound of water raised 1° Fahr., exerts a force equal to raising 728 pounds to the height of one foot. These data are confirmed by many other philosophers working on the same subject, and, simple as the results may appear, they have cost the noble men who established them years, and in some cases lives, of toil and research. We too often avail ourselves of the natural laws they have discovered without a due sense of gratitude. Our calculation now becomes very easy. To determine the amount of water which one pound of coke will evaporate at 212°, we have only to deduct the ashes and water it contains; the carbon (C) then left, multiplied by

* These for convenience are termed units of heat. The amount of heat necessary to elevate 2.204 lbs. of water (=1 kilogramme), from 0° Cent. to 1° Cent. is assumed as unity.

its heating power 13,268, and divided by 965.7, gives the number of pounds of water which the coke by itself could evaporate

$$\frac{C \times 13{,}268}{965.7} = x$$

or arithmetically expressed, suppose a quantity of coke dried at 212° weighs 53 lbs, and contains 6 per cent. of ash and other impurities, we have then to deduct 3lbs, leaving 50lbs. of carbon, then $50 \times 13{,}268 \div 965.7 = 686.9$, being the number of pounds of water the coke could evaporate. The actual theoretic duty of a pound of coke or coal we may express by the number of pounds raised to the height of one foot, and this may be readily obtained by the simple formula

$$Wp \times 965.7 \times 782 = x$$

W representing water, of which P, pounds, are evaporated by a pound of coal. The theoretical value of coal, with reference to the number of pounds of water which one pound of fuel will convert into steam, is obtained by the formula

$$\left(\frac{C \times 13{,}268}{965.7}\right) + \left(\frac{H\text{—}h \times 62{,}470}{965.7}\right) = x$$

in which C is the quantity of carbon, H the quantity of hydrogen in an unit of Fuel, and h the quantity of hydrogen corresponding to the oxygen contained in the coal. These multiplied by their heating powers, according to the results of Dulong, and divided by the latent heat of steam, indicate the number of pounds of water that can be converted into the latter by a pound of coal. The numbers thus obtained can be changed into the expression of mechanical force, by the previous formulæ. These data assume the water to be at a temperature of 212°, but as some heat is always taken up in heating the water from the temperature at which it is fed to the boiler, this must be calculated and added to the evaporative power given before, thus:—suppose the water to enter the boiler at 52°, then each pound of water will absorb 161 units of heat to raise it to 212°, or nearly one unit of heat for each degree of temperature; this must be calculated and added to the value of the fuel as estimated by the foregoing data. Suppose the

evaporative value of a coal, found by the forms before given, were equal to 10.75, then—

$$\frac{10.75 \times 161}{965.7} = 1.792$$

This added to 10.75 is 12.542, the true value of the coal. The corrections for barometric pressure, the hygrometric state of the atmosphere, and the small amount of combustible matter in the clinkers or residue, are not necessary in ordinary practice. "The "only omitted correction which, in appearance, might be supposed "necessary for practical purposes, is that for the hygroscopic "water," and Messrs. De la Beche and Playfair state that "had "they introduced corrections for these small quantities, practice "would have been misled, because the coals will rarely reach a "vessel in the dry state in which they did in the present case, when "they were packed in hogsheads and kept under cover." The reports give, separately from the analysis, a table of the hygroscopic water found in many of the coals; but this will only apply to them under the circumstances described, and not as they come into the market for sale; this will vary almost daily with the weather, and to be of practical value the water must be ascertained when the coals are purchased. In the late analysis of Cardiff coals, by Messrs. Millar and others, to which we shall hereafter refer, this plan has again been followed, and they call special attention to it. The practical trials upon the evaporative power of coal, described in these reports, are the only points disputed.—The trials were made under a boiler giving, as nearly as could be, the same conditions as the form then used in the steam navy; the distinct instructions of the Admiralty being, that the value of the coals for use in the steam navy should be ascertained; the reports give this; and in order that no one may be led to believe that these are the practical value of the coals, under every condition and form of boiler, they made a series of experiments under a Cornish boiler, and obtained about twenty per cent. more duty from the coal. —We now take the main points in the reports secondly referred to, viz.: the coals of the "Hartley District" by Messrs.

Armstrong and others; these reports were made for the "Steam Collieries Association of Newcastle-upon-Tyne;"—the experiments seem to have commenced some time in 1855, and to be ended January, 1858. They commence the first report (25th Aug. 1857,) by stating that "the task of awarding the premium of £500 "which the Association offered in 1855, for the best method of pre- "venting smoke during the combustion of the coal of their district "(*i.e.* the Hartley District) in marine engine boilers, has been so "great, that they are not in a condition to report finally thereon." They give us no details of their experiments or of the data they used, except, the "coal burned per square foot of fire grate per "hour; water evaporated from 60° Fah. per square foot of fire "grate per hour; total evaporation per hour from 60° Fah.; water "evaporated from 212° Fah. by one pound of coal." An apparatus was attached to the boiler, by which the feed water was partially heated by the waste gasses of the chimney. They assert "that the "experiments were made with a boiler of the ordinary multitubular "construction," and conclude by stating that "We are at present, "however, able to state that under the most favourable conditions, "the Welsh coal does not exceed the Hartley's, either in the amount "of work done in a given time, or in economy; and, under the "general circumstances of steam navigation, falls short in both "particulars." The second part (January, 1858) states that "the "boiler built for the experiments present no peculiar features, "and we annex a drawing to shew it is only the ordinary "type of a marine multitubular boiler, such as is generally "considered to present the greatest difficulty as regards the "prevention of smoke;" the smoke consuming plans sent in for burning West Hartley coals were 103 in number, and the way in which the fire-bars and surface were altered for the different plans is described. The result of all this is that the plan proposed by Mr. C. Wye Williams, of Liverpool, is approved, and at page 18 we see stated that "no particular attention is required from the "stoker, in fact, in this respect, the system leaves nothing to desire, "and the actual labour is even less than the ordinary mode of

"firing. Mr. Williams's system is applicable to all descriptions of "marine boilers, and its extreme simplicity is a great point in its "favour; it fully complies with all the prescribed conditions." We notice at page 21 it is stated, the mode of firing is, as usual with bituminous coal, to charge on the dead plate and push forward as required. Page 22 states that furnace management is an art men must be properly instructed in, and then kept to their duty; otherwise, by bad construction and negligence, the economic value of the fuel may be reduced one-third. The conclusion is again the same as at page 17, first part, and simply an affirmation that West Hartley coals are better than Welsh coals. The third report (same date as last, January, 1858), describes a trial of what is termed by them "best Welsh coal," under the boiler before described; it does not give us the name of this coal, but states it contains 20 per cent. of small, and assumes that all "Welsh coals are liable to very great "deterioration when kept in store;" the Welsh coal evaporated 12.35 lbs. of water, and the West Hartley 12.90 lbs., both from 212°, and in every other respect the latter was found far the best. The report concludes by stating that the absence of smoke was the cause of the extensive use of Welsh coal. "But beyond this it "was the report in question which first gave the Welsh coal its high "character. It was the consequent extensive adoption of this coal "by the steam navy and public companies which gave to this cha-"racter the apparent sanction of practical experience. The figures "of the reports were implicitly believed in, although from the be-"ginning there were many who doubted, but their opinions being "attributed to interested motives could carry no weight against "government authority and government practice, and so a grievous "error eventuated in a grievous injury both to your district and to "the national interests." The former part of the paragraph we will refer to hereafter. The three reports are marked by personal allusions to Messrs. De la Beche and Playfair, and strong assertions that there was something wrong about their report, and they had done "grevious injury both to the West Hartley District and to "the national interests," but not a single scientific point or experiment to the purpose is raised or brought forward to prove this. On

examining these reports we find they admit at the commencement that the experiments are of a partial character, and to determine the best method of burning the coals in the Hartley District. We have no details of the experiments and cannot tell how to check them; this is quite contrary to the rules and present practice in scientific enquiry. We are next told the boiler is of the ordinary multitubular construction, and this is again afterwards repeated, as if to make some point; but on referring to the Government report, by Messrs. Miller and Taplin, which we will hereafter notice more fully, we find they state (page 18), "That (the boiler) at Newcastle "was obviously made specially for experimental trials of a peculiar "coal. Its proportions favour in a remarkable manner the com- "bustion of Bituminous coal. The two furnaces were large and "roomy, and, by presenting a wide and high front, were well "adapted, and apparently designed, expressly for the application of "Mr. Williams's patent smoke preventer. Beyond the fire bridge "there was a large heat-chamber, where the unconsumed gases that "might accidentally escape beyond the bridge were mixed and in- "flamed; so that, practically speaking, almost perfect combustion "was obtained with a higher temperature than is usual passing "through the tubes. This was well illustrated by sight holes made "in several places behind the boiler, through which, during the "many experiments that were made, the luminous appearance of "the products of combustion as they passed over the bridge might "be clearly seen; but this enlargement of the boiler at that parti- "cular part involves consideration before such a description of "boiler could be applied to steam vessels in Her Majesty's navy. "Still I believe it to be undeniable that the large amount of success "at Newcastle resulting from the practical experiments on Newcastle "coal, is greatly attributable to the spacious heat-chamber above "referred to." These statements are so totally different, and involve results so serious to the subject we are reviewing, that we must now be doubly careful to examine the evidence, one assertion or the other must be wrong; an inspection of the Newcastle boiler, the drawings of which are before you, will enable you to decide. "The plan of Mr. C. Wye Williams's system, as is well known,

"consists in the admission of air at the furnace door, or at the "bridge, or at both, by numerous small apertures, with the inten- "tion of diffusing it in streams or jets amongst the gases." We must again bring facts and experience to bear upon this. About 1839, or some twenty years since, Mr. Williams obtained a patent for this very plan of economising fuel; all that is now stated in the reports before us, and much more, was then hoped from it. Almost every member present has read Mr. Williams's "Treatise "on the combustion of coal," or his prize essay, from the Society of Arts, on the "Prevention of the Smoke Nuisance." Few persons dispute Mr. Williams's theory. It is based on laws at present generally admitted as proven, but the practice and working results have yet, it seems, to be dealt with, and this is the main subject before us. To insure the utility of this plan, the valves or openings to admit air to the fuel must be very carefully adjusted from time to time, the outlet of the chimney stack must be watched closely, as also the fire in the furnace. If too small a supply of air is given soon after firing the smoke is not prevented; if this supply is allowed to continue the same the fuel is wasted; and when several fires, as in all large steamers, run to one chimney or stack, then it is most difficult to ascertain the state of the fires requiring air or otherwise, and when the smoke is prevented a large proportion of fuel is often burning to waste, almost without possibility of detecting it; and at sea, in rough weather, the stokers, if they were capable, are too busy to attend to the valves, and they shut them up altogether. It is strong evidence of the impracticability of the plan, that in the great port of Liverpool, after twenty years experience (and where the inventor has much influence), the use of the plan with very trifling exception, is confined to a few steamers plying in the Irish Channel, and scarcely known in practice, or to any extent by the ocean-going steamers: in fine weather, if the coal smokes, the stokers leave the door of the furnace slightly open for a short time after firing, and use this plan instead of the valves referred to. The experiments on Welsh coal were confined to one sample,—we are not informed from what district or place in South Wales; and the assertion, that as a class all Welsh coal is liable to great deteri-

oration when kept in store, is so contrary to the experience of the West India Royal Mail Co. and other firms, as to compel us to class this with the former conclusions arrived at in these reports. We cannot but feel pained to see in those reports, an attack on the character and reputation of two gentlemen, who, from their genius and true work done to science and human progress, deservedly rank with the leading men of the age; after many preliminary personal allusions, they close the impeachment by asserting—"Messrs. De la "Beche and Playfair to have committed in their reports to the gov- "ernment, a grievous error, eventuating in a grievous injury, both "to the West Hartley District and to the national interests." We must bear in mind that these serious charges are made without the slightest attempt to prove them in any way by the laws of evidence, and such attempt, as we shall hereafter shew, would, if tried, be futile. The facts as to these reports are, that during the five years they occupied, pecuniary grants were made at different times by the government for their prosecution, to the amount altogether of £2639; for machinery, apparatus, aud all the labour and work, this sum was far too small for the effectual prosecution of the enquiry; the reports of the French and American governments had been made on the same subject, and the scientific reputation of our country was, to some extent, involved in our doing our part truly and well. The patriotism of our men of science now came to the rescue; Sir H. De la Beche and Dr. Playfair resolved to forego any pecuniary compensation, their five years' work was given freely to their country, and their noble example induced their excellent assistants to accept a mere pittance as salary, to enable the work to be carried out; these gentlemen were not associated with trade, they had no interest in any way but the search for truth, and time and experience confirm the positive accuracy of the results they arrived at. These "grievous" personal accusations in the West Hartley report, appear to me so unfounded, that without further remark I may leave them to recoil upon their authors. The report of Messrs. Hoffman and others to the "South Wales Coal Owners' Association," now follows: this seems to be simply a confirmation of De la Beche and Playfair's reports. No coals are reported

on here, but those from the Aberdare Valley only; the best of the South Wales Coals (according to the government experiments) viz: the Ebbw Vale, is not referred to in either the West Hartley or this report; this coal was far better for trial with the West Hartley than the semi-anthracite of Aberdare, as it can be adapted to any usual form of boiler. It would have prevented some confusion, if a more definite title were used by this association, as the reports are confined to Aberdare coal, and South Wales coals generally are not in any way represented or examined; and the association at present has only a local character, and represents only a portion of the district or coal owners of South Wales. All we have, as to the practical details of any experiments, we find in the reports by Messrs. Millar, Taplin, and Lynn. The fourth series of reports, by Messrs. Millar, Taplin, and Lynn, states that they are directed by the Admiralty to report upon the experiments of the North of England and the South Wales Collieries' Associations; they explain in part, how far the experiments are conducted by both parties, and regret the difficult position they are placed in "from the spirit of "rivalry actuating the parties concerned;" and plainly intimate that neither of them are really searching for truth. They report "that it is possible to consume the smoke arising from North "Country coal by the use of Mr. Williams's apparatus;" but they give no opinion as to its practicability in regular work at sea. They state that "when the smoke from the North Country coal is "consumed, its evaporative value is nearly equal to that of Welsh "coal," but "these comparisons are only made upon the supposition "that the smoke from the North Country coal may be reduced to "the same minimum as that which may arise from Welsh coal." Mr. Taplin was afterwards (27th Jan., 1859) directed to report "fully on the merits and value of the South Wales and North "Country coals." After shewing in the appendix to these reports, the difficulties in making any satisfactory report on the subject under present circumstances, he declines giving any opinion. The fifth and last evidence we have to examine, is the actual experience of the principal ocean-going steamers, where economy in weight of fuel is absolutely necessary for their success and existence. The

assertion in the West Hartley reports, that the Admiralty reports "first gave the Welsh coal its high character," is incorrect. The free-burning coal of South Wales was the earliest used for ocean steam navigation; about 1837 a series of experiments was made at Bristol with different coals, the object of which was to determine the coal to be used in the *Great Western* in her first voyage to America; the superior character of the coal was fully proved by experience, and was one great source of her success. Ocean steamers were soon multiplied, and Cunard's Line, the West India Royal Mail Co., the Peninsular and Oriental Co., and others were established, all these using Welsh coal. At the time the Government reports were published an opinion prevailed that none other but Welsh coal could be used for long voyages; these opinions are now somewhat modified,but yet we have the practical fact before us, that after these many years experience and trials on a large scale of the different coals found, not only in Great Britain, but other parts of the globe, nearly all the Ocean-going steamers of every nation still use the Welsh coal. The Ocean-going steamers from Liverpool are the "Cunard" and the "Collins" Lines, both celebrated, and, perhaps, for the speed and regularity of their work, are not equalled. The country around Liverpool abounds with coal, cheaply worked, yet we find these steamers entirely supplied with Welsh coal, conveyed by railway about 150 miles, or subject to an equally expensive transit by sea. In the Port of Southampton, the Home Station for the West India Royal Mail Company, the Peninsular and Oriental Company, and others, Welsh steam coal is exclusively used by some, and mostly by all these companies. The small proportion of North Country coals consumed is, not as the Welsh supplied generally under contracts, but taken as a last resource in case of short supplies from Wales. Numerous other cases like these may be quoted, but are not necessary here. These great Steam Navigation Companies are the jury empannelled to try this issue from time to time; for as new improvements are made in machinery, new conditions arise as to the economic use of the fuel, this jury are, under the heaviest penalties, bound themselves to try the question fairly and give a truthful ver-

dict, and from their verdict commercially we have no appeal. The conclusions I arrive at from the mass of evidence examined and submitted to your consideration are—

1st.—That the reports of the West Hartley and South Wales Coal Associations give no new scientific data, and the practical experiments, as proved by Messrs. Miller, Taplin, and Lynn in their reports to the Admiralty, and the facts now laid before you, are of little value as evidence, and calculated to mislead.

2nd.—That the reports made to the Admiralty by Sir H. De la Beche and Dr. Lyon Playfair are the only reliable scientific works we have on the subject, and at present the results of their practical, or economic experiments, are not much altered by mechanical improvements in utilizing the fuel; and this is completely proven by the fact that the Great Steam Companies referred to do not use largely any other than the South Wales steam coals; and that these Companies, using and experimenting at sea upon nearly one million of tons of coal annually, are far better able to form an opinion of the true practical value of the coal than can be done by single experimental boilers on land.

3rd—That any attempt for the owners or vendors of coal, or any mercantile commodity, to settle the relative quality for the consumer or vendee is wrong in principle, is in itself absurd, and must be futile. The consumer will always try to buy the best article for his purpose in the cheapest market. The superior theoretic value of the South Wales steam coal is an established truth, and not disputed. The fact that, after long experience, the Great Ocean Steam Companies now buy and use almost exclusively South Wales coal, is unanswerable evidence of its practical superiority.

Mr. Greenwell enquired if he might be permitted to ask—whether the President had been reading a paper, written, of course prior to the discussion, and giving his own individual opinions, or

whether it was to be regarded as a summing up on behalf of the Institute? For if the latter, he for one felt bound to protest against it. (See notice on cover of each number.)

The PRESIDENT replied that it was part of his duty to sum up the evidence adduced at any discussion, as a judge was required to sum up to a jury; but there was frequently a great difference between the summing up of the judge and the *verdict* of the jury. It must be taken for what it was worth as a summing up of the discussion, according to the best of his ability.—The opinions expressed by him were his own, and not in any way to be taken as those of the Institute as a body; and he should ask them not to give any opinion, for, as he had already stated, the great Steam Companies of the kingdom would be the proper jury, and from their verdict there would be no commercial appeal.

Mr. GREENWELL said that the explanation of the President was perfectly satisfactory.

Mr. Cox understood that in his summing up the President had stated that the hygroscopic water of coal was of no consequence, as it only existed in it when fresh from the pit, and had evaporated before it came to be used.—This he must contradict. As a manufacturer of gas, he had found that some coal that had been kept perfectly dry and sheltered from the effects of the rain for months, yielded as much as 8 per cent. of hygroscopic water; even had not this been the case, as coal was purchased now generally on the day it was raised, the evaporation of the water in the transit would not effect the question, as it would have been paid for. The report of Messrs. Miller and Tamplin contained two calculations; in one they put the latent heat of steam at 906, and the other at 988. He could not see that the comparative value of the coals could differ in the two calculations, yet a reference to them would show that it appeared to do so most materially; common sense would tell them that this could not be truth, and that there was a great mistake somewhere.

The PRESIDENT said Mr. Cox had misunderstood the remarks on the water in the coal.

Mr. FRYAR said there were one or two more points referred to by Mr. Roper that he wished to allude to. He had remarked that the quantity of peat in this country was very small, it might be so, though he understood otherwise, and he had noticed the objection taken to the quantity of ash contained in this fuel. In some of the Irish peats, such as those from the Bog of Allen, the proportion was not more than 3.7, but in some from the vicinity of Tuam, a mean of as much as 37 per cent. was found. In some kinds very little ash was found, while in others there was a very large quantity.

The PRESIDENT said that so much time had been occupied in the discussion of the papers on fuels, he regretted to be compelled to ask to postpone the other papers to the next meeting. At the same time he could not but congratulate the members on their having so many papers of such a high character to read, as after all, these contributions formed the true basis of the Institute. They now found they had them not only in sufficient numbers to make the meetings of special interest, but, also, bearing abundant evidence of labour and thought; and the Institute was deeply obliged to the contributors of these papers.

The Secretary then read the following paper :—

ON THE MANUFACTURE OF STEEL.

By Mr. ALEXANDER WILSON.

I HAVE undertaken to lay before you this paper on the manufacture of steel, not for the purpose of entering into any chemical analysis of the various kinds of steel, but more with a view to give a description of the present recognized mode of its production, and a general idea of its rapidly extending application.

It is a subject of great national importance, and will also be full of particular interest to many, since it not only assists so materially the operations of the iron work, but threatens to supersede iron altogether, in several of the important branches of industry of this country.

Steelworks have long been established at Sheffield, Birmingham, Newcastle-on-Tyne, and one or two other parts of England;—but Sheffield has always been looked upon as the chief seat of the trade, having naturally in its possession a number of advantages, enabling it to take the lead of all other localities. Among these advantages may be named its situation in the Yorkshire coal-basin, which contains all the varieties of coal for hard and soft coke, and, also, the converting coal, which the different processes require. A few miles distant from Sheffield there are no less than 31 seams of coal, in a vertical section of 700 yards,—more than half of which are of sufficient thickness to be most profitably worked.

The stone for the lining of the converting and melting furnaces is easily available, being well adapted to stand an intense heat.

Also, at a short distance is found, lying at the bottom of the coal measures, alternating with sandstone and shale, that peculiar black clay for the melting pots, being the only kind yet known that will bear the intense heat of the melting furnace.

Water power is also very abundant in the neighbourhood of Sheffield, which was of paramount importance before the introduction of steam power; and upon the various streams that flow through and past it, were erected the tilts, and forges, and grinding wheels required in the manufacture of steel.

England not being capable of supplying a suitable article, the steel manufacturer of this country has always been dependent upon Sweden and Russia for his supply of the better kinds of wrought iron,—from the fact of their being made with charcoal only. The ores of Great Britain are more difficult to reduce and obtain free from sulphur than those of Sweden and Russia; and the use of coke further deteriorates their quality for steel making, as is proved by several experiments made upon Swedish pig when wrought into bars in a coke fire. Even Swedish blooms, which have been heated and welded by coke and rolled into bars, are found to absorb deteriorating elements.

In one point of view, the iron manufactured in this country is superior to any manufactured abroad, being sounder and more regular, from the superiority of the machinery employed.

The various qualities of the Swedish and Russian wrought iron imported, are distinguished by what are called trade marks, stamped on the bars. There is an endless varity of them, but "Ⓛ" (loop L) made from the famous Denemora ores, has always enjoyed the character of being the best brand, and certainly has maintained the highest price.

There are several other Swedish irons such as "G. L." and "double bullet," that rank beside Ⓛ in point of quality.

A well-known Russian Iron produced on the estates of Count Demidoff, called C C ND, is used largely in Sheffield for certain purposes. The magnetic ore of Sweden is very abundant, but the

quantity of Iron made from it every year is limited by the quantity of wood that can be obtained, and also, the Swedish forges being almost entirely dependant upon water for their power, a dry winter limits their make, as is experienced in the present year, 1859.

The Swedish iron is most generally hammered from the bloom, Rolling Mills being but seldom used, which are now being introduced, but at present are principally applied for the production of iron for smiths' purposes, of which large quantities are annually exported to North and South America, India, and other distant countries, being chiefly applied to such purposes as the manufacture of horse shoes, wheel tyres and agricultural implements.

Swedish pig iron, the exportation of which was until very lately prohibited, is now being imported in quantities into this country, for the purpose of making the best irons for mixing.

The peculiarities of these various irons, it is said, are so remarkable, that by means of the most accurate chemical analysis there cannot be detected any difference, between a given kind of iron which produces a superior, and another kind which produce an inferior steel.

The iron principally used is a soft fibrous wrought iron, and of a peculiar silvery whiteness, shewing, more or less, a crystalline fracture.

Within the last few years some of the leading Yorkshire and Staffordshire houses have been engaged in producing a quality of iron for steel purposes; but which can only be applied, with any degree of success, in the manufacture of the common class of steel goods, such as low priced saws, hoes, forks, and some varieties of springs. Its quality for steel making is not to be compared to anything imported from abroad, for it is almost invariably found to be much shorter in its character as steel, and less easily welded; nor will it stand so much fire, and it does not absorb the carbon freely. Notwithstanding, we anticipate the day will arrive, when skill and perseverence in this country will triumph, and we shall be manufacturing for ourselves a class of iron that will render us somewhat more independent of foreigners than we are at present.

I shall now proceed with the first process in the manufacture of steel, which is known by the terms "cementation" or "converting."

The converting furnace consists of two rectangular chests made of siliceous freestone capable of withstanding a high temperature. These chests are generally about 14 feet in length, and from 3 feet to 3 feet 6 inches in depth and breadth, and placed about 18 inches from each other.

The fire, which is placed underneath and extending the whole length of the furnace is allowed, by means of flues, to pass between and on the other sides of these chests in which the iron and charcoal are located; an arched brick vault is made to cover all these, and the smoke and heat escapes by three flues on each side of it into the large conical part of the furnace, which is generally constructed about 30 or 40 feet high, in order to prevent the smoke being troublesome, and also that the wind may not interfere with the draught. This form of conical part is also used to ensure an uniform draught through all the flues surrounding the chests, so as to produce as equal a degree of heat as possible throughout the body of iron; a most essential part of the process of conversion or cementation: for without this no uniformity of temper in the steel could be obtained.

The arched vault has an opening at each end, sufficiently large to allow the men to enter when it is required to fill the furnace or draw it. When the conversion or cementation process is going on these openings are bricked up temporarily. and plastered over with wheelswarf to exclude the air. On each side of the entrance for the workmen are two openings. about a foot square, through which the iron bars are introduced by a man outside to those within. The whole of these require great care in their construction, in order that the atmospheric air may be completely prevented from effecting any entrance while conversion is going on, as the presence of oxygen is fatal.

After the furnace is prepared to be charged, the bottoms of the chests are covered to the depth of about a couple of inches with wood charcoal, and carefully smoothed down. The iron bars being next

introduced, are laid on their flat one beside the other, till the breadth of the chest is filled up,—this layer is then covered over with a coating of charcoal half-inch thick; upon which is placed again a layer of iron, then charcoal, this being repeated till the chests are nearly full. The whole is finished with a thicker layer of charcoal than usual, which is covered to the depth of several inches with wheelswarf to protect the steel underneath from the action of the air. In the centre end of one of the chests is a square opening, which is continued to the exterior of the furnace, into which are placed several bars called trial bars, to be extracted at different times during the conversion that the progress made may be known, and the correct working of the furnace ascertained. All the openings are now carefully closed up and the fire lit, which requires to be gradually increased till a cherry red heat is obtained, and which will now call for unremitting watching day and night for from eight to ten days, according to the temper of the steel that is required. A dimunition of the heat from the time of starting occasions a loss of fuel and is also injurious to the chests.

The charcoal used and preferred, is that generally burnt from hard wood, the whole having been ground and passed through a sieve with a quarter to half-inch meshes, so as to obtain the proper size of the charcoal.

Eight days may be considered a sufficient time for producing steel sufficiently carbonized for spring purposes. Shear steel and steel for common cutlery require a longer period, and the higher qualities of cast steel a longer period still; generally over ten days.

The quantity of iron that these furnaces contain varies very much, some being large enough to hold 30 tons and others as little as 15 tons. But the smaller the furnace the more uniform is the temper of the steel, though the cost is more. The sizes of iron depend entirely upon the purposes they are intended for, some having to be square, others octagon, but they are generally flat. Thin bars work faster and make more regular steel than thick and heavy ones;—the latter are more or less semi-converted inside, while their exterior is highly carbonized.

The regulation of the fire is rather a delicate operation, and is managed solely by the skill and experience of the workmen. If the heat is allowed to become too great and continue so, the wrought iron will be converted into cast iron or something akin to it. The coal preferred for converting is what is called a hard coal,—such as will burn clean in a good draught, and leave no obstruction on the grate bars. Each firing will take from 4 to 5 cwt. of coal—requiring to be repeated every two or three hours. A heat of steel will consume on an average about 13 tons of coal, but it is difficult to arrive accurately at the result as the consumption depends on many contingencies. As many heats as 21 have been got out of one furnace in 12 months, but the average is below that.

When from the appearance of the trial bars it is judged necessary to arrest the carbonization the fire is withdrawn, and for two or three days the furnace requires no attention whatever. The bricked-up openings or manholes, in the arched vault, after this period are broken down at each side of the furnace, and a current of air allowed to pass freely through it which soon cools the interior sufficiently to permit a man to enter and break open the chests, and take out now what is usually called "blister" or "converted" steel. As might be expected there will be found some little want of uniformity in the temper or hardness of the bars, some being barely converted in the interior, while their exterior will be overdone.—This is owing to some parts of the chests being more exposed to the action of the fire than others. The thickest bars should always be placed in the hottest part, and the thinner and also inferior qualities where they will get the least fire.

Blister steel after being taken from the furnace is very brittle, the hardest bars being most easily broken while in the blistered state; the presence of fibres indicates that the conversion has not been completed, the fibre in iron being completely destroyed when thoroughly converted into steel.

The grains of good steel appear like globules, and the fracture should present a creamy colour and a bright lustre. That

which exhibits a fine grain of crystalline form, and of a white colour, is known at once to be a poor article.

Some say an indication of good iron is its increase of weight when converted, gaining as much as 21 per cent. Bad iron neither looses nor gains, and blisters but little on the surface. When the iron is good the blisters are regular.—These blisters are supposed to be owing to impurities contained in the iron, which take the gaseous form on being heated, and are finally expelled when the steel is melted; for when cast steel is placed in the converting furnace a seeond time, it is never found to blister.

In consequence of the irregularity of temper in the contents of the furnace, the bars after being taken out have their ends taken off, and are then assorted, and laid aside to be applied to the different purposes they are particularly suited for. During this operation, if the atmospheric air has been allowed access to the iron while undergoing carbonization, its effect is to decarbonize it to a depth varying from the thickness of a piece of paper to the one-tenth part of an inch; it is at once detected by the soft irony appearance of the skin, which though tough will not harden, necessitating the return of these bars to the converting furnace. The blistered steel intended for spring purposes, is taken away to the rolling mill, and there heated in the furnace to a red heat; and after passed through the rolls and drawn down to any thickness. This is the most extensive use to which blistered steel is applied now.

Another, and a very important use to which it is put is the manufacture of shear steel, having derived this name from the fact of the blades of the shears for cutting woollen cloths being made from it. Great care has to be exercised in its manufacture.—The blistered bars are taken and heated to the usual red heat, and drawn down under the hammer to a convenient size, usually $1\frac{1}{2}$ or $1\ \frac{3}{4} \times \frac{1}{2}$ or $\frac{5}{8}$.—Six or eight of those bars are then taken, placed upon each other and securely fastened at one end, into a pair of tongs for the purpose. They are next put into a hollow coke fire supplied with a blast, which is increased gradually till the welding point is at-

tained; in the meantime the surface is kept covered with clay beaten very fine, to prevent oxidation and decarbonization at so high a temperature. When it is sufficiently heated it is placed under the beavy forge hammer and welded together. These hammers are upon the lever principle, being lifted by being depressed from behind by the action of revolving arms.

In welding the speed requires to be very slow, a short interval elapsing between each stroke. After the weld is completed the speed is increased and the elongation of the bar begun. Half of the bars are only finished at one time, so that the end which has been welded is next placed in the tongs, and the other heated and treated in the same manner as the first. Being finished it is put aside as single shear steel.

To produce double shear, the single shear bar is broken in two pieces, laid upon each other, fastened in the tongs, heated and welded and hammered out as before. By this double operation the steel becomes very much denser and better adapted for cutting instruments. There is one drawback however, to this method of treating steel, and which deters many people from using double shear for taps and other very particular purposes, from its extreme liability to crack in hardening. This tendency to "cluck" is caused by the compulsory use of the powdered clay when the steel is being heated to the welding point. The clay-fusing runs between the bars, and should any be suffered to lodge during the forging, an unsound bar is produced,—which is soon discovered when tried to be made into a tap or used for shears.

Some years ago files being made of blister steel consumed large quantities of it, but they are now invariably—at least the better qualities—made from best refined cast steel.

Cast steel is perhaps the most important change the iron undergoes; the irregularity exhibited in the texture of common, or blister steel, gave rise to its invention: the steel selected for this operation is more highly carbonized than usual, as in melting it looses a portion of its carbon. The heat required is of the most intense description, necessitating the furnaces to be constructed in

such a manner as to be capable of raising this pure white heat without the assistance of artificial blast, and of enduring it without immediate injury.

The chambers or holes in which the crucibles are placed are about 3 feet 6 inches deep to the fire-bars, by about 18 inches square, the top of them being on a level with the furnace floor in order to facilitate the pulling out of the crucibles. From 6 to 20 of these melting holes are placed in a row, according to the extent of the works, Each hole has a separate ash-pit underneath, the height from the fire-bars to the floor being 5 feet, and the width only the same as that of the hole itself which contains the crucibles. The Flues of each hole are also kept quite distinct from one another, and carried to the height of 35 feet; by all these arrangements, and a copious supply of air underneath the enormous heat required to melt steel is thus obtained.

The very best hard coke that can be obtained, and as free from sulphur as possible, is employed for melting steel.

The crucibles are made adjoining these furnaces in all large works, from the clay so admirably adapted to withstand a high temperature, that is found in abundance the neighbourhood of Sheffield and in Derbyshire. It is got in the dry state in lumps, then powdered, sprinkled with water, and kneaded most thoroughly with the heel. After this has been accomplished the quantity necessary to form a crucible is weighed off, which a man takes and throws upon a cast iron table for some time, to expel from it all the air and to make it as dense as possible, that a perfectly sound crucible may be ensured. It is next placed in the bottom of a cast iron mould of the form of the crucible. A wedge is then driven through the clay—a tapered circular wedge of course—which causes it to be forced up between the mould and wedge until it reaches the top. The wedge is then withdrawn, the top of the crucible is finished off with a knife, and slightly narrowed by passing the knife round several times between it and the mould, keeping the knife inclined to the centre. The mould has a moveable bottom with a hole of $\frac{7}{8}$ diameter in it, unto which fits a guide fastened in the wedge to keep it

working in the centre. Each crucible has a hole therefore in its bottom. The mould is lifted on to a circular piece of wood, which thrusts the bottom to the top, carrying with it the finished crucible. They are taken away and stored in the melting room to be dried before used.

The first preparation for melting is the annealing of the crucibles, which are gently heated in a furnace close at hand. They are next placed, covered with a lid, in the chambers, each chamber containing two crucibles, and made to rest upon a circular piece of clay about $2\frac{1}{2}$ inches thick which the intense heat causes to adhere and stop up the small hole left in the bottom when made. A fire is then kindled, and the crucibles are ultimately covered with coke, and when they are at the temperature at which steel melts, the lids are removed and the blister steel, previously broken into small pieces, weighed, and selected, is introduced by a long funnel. Each crucible melts from 28 to 40 lbs. of steel. The lids are put on again —more fuel is added if necessary, and the chamber cover replaced; the fires now requiring watching from three to four hours. In the meantime the moulds, made of cast iron, and into which the steel is poured, are being got ready. They are vertically in two halves, and require to have their interiors smoked, by burning tar underneath them, to prevent the steel from adhering to the cast iron. They are next fastened up with iron hoops, and wedges driven in between them and the moulds. Two of these moulds are taken and made to stand nearly erect in a hole in the floor. The order being given to pull out the crucibles, the chamber cover is cast aside, one man introduces a long pair of tongs, clasps one pot, and immediately brings it to the surface, swinging it over beside the mould. The slag and coke adhering to it are cut off, the man who pours or "teems" now takes hold of it by a pair of tongs; the cover is removed by another, and the cast steel is then slowly transferred to the mould. The pot, if a good one still, is returned to the furnace and filled again. The greatest amount of attention and care has to be paid to the pouring, from the extreme suddenness with which the steel passes into the solid state. All the doors and windows

have to be closed to exclude the least draught of cold air. Three pourings take place in one day of 10 hours, and after each, the ingots are taken out of their moulds, and carried to cool.

It takes from four to five tons of coke to melt one ton of steel. When larger ingots (say about 70 lbs.) are required than one pot of steel can produce, two crucibles are simultaneously taken out of the furnace, the contents of one poured into the other, and then the whole poured into a mould sufficiently large to contain it. When larger ingots still have to be cast, the moulds are prepared as before.—Four pots are then brought out, and the steel of the four poured into two. A man takes hold of each crucible, one beginning to pour first; when he has nearly done the other commences, the same being repeated till the ingot is complete. If the stream is suffered to be stopped for a moment during the filling of the moulds, the ingot will be spoilled; and this is the great difficulty we have to contend against in endeavouring to get very large ingots of cast steel. There is another important matter that causes much annoyance in the making of steel ingots, and which is called piping. The top part of the ingot is nearly always hollow, and requires to be broken off before it can be wrought into the bar, else the bar would be unsound if it were suffered to remain. This piping extends for several inches. In consequence of this the waste becomes a serious item.

Mild cast steel and cast steel for welding are always melted when the crucibles are in the best condition, requiring more time to fuse them. The harder sorts, such as that used for saws and files require a less time.

After the ingots have been formed, they are next taken to be submitted to the hammer to be drawn into bars. They are heated to a cherry red heat in a similar furnace to that used in the heating of shear steel. The tilt hammer requires no description being well known to almost every one. Three hammers form the set usually, and are driven by a steam engine set apart especially for it and also water power; for if the engine was connected with any other machinery, the speed of the hammers could not always be regulated

as desired. The tilt hammer runs at the rate of from 250 to 400 strokes a minute, depending upon the sizes of steel required,—running slower to draw a six foot bar than an eight foot, as they have to be done at the same heat and, therefore, in the same time. The weight of the hammer is about 2 cwt., the spring anvil behind making up the effective blow to about 3 cwt. But the quicker each stroke succeeds another the heavier it is, in consequence of the increased rebound off the spring anvil behind. The tilt is only used for drawing steel from three-sixteenths to seven-eighths square, and flats in proportion. All sizes above that are taken to the forge hammer. This weighs from $3\frac{1}{2}$ to $4\frac{1}{2}$ cwt., increased by the spring anvil to $4\frac{1}{2}$ and $7\frac{1}{2}$ cwt. respectively. Its rate is comparatively slow, giving only 150 strokes a minute.

Half the bar only is drawn at one heat, when this is finished and allowed to cool, the other half is treated in the same way. In making round bars a stream of cold water is allowed to play upon the bar at the point of contact with the hammer when about finished to clean its surface. The beautiful blue colour is given by continuing the hammering till it cools down to what is called a very dark cherry red. Each man's work being taken account of, it is removed to the wharehouse to be carefully examined before being sent away. All the ends require to be broken off being more or less unsound, occasioning another waste.

Cast steel is applied to an infinite variety of purposes, and always where cost is no object. From the processes it passes through it is rendered more homogenous, and sounder than any class of steel. It is now used very extensively in the manufacture of railway springs, it being found that when made of cast steel they are very much more durable and carry a greater load. The ingots for this purpose are subjected to the metal helve before they can be passed through the rolls, receiving what we call a "washing heat," and making it perfectly uniform and sound. The metal helves employed weigh about 75 cwt. and give a stroke of 2 tons,—their speed being 100 a minute.

The rolls used for spring steel drawing are 12 inches diameter,

turning at the rate of 60 revolutions per minute. The sizes of steel rolled are from 3 × five-sixteenths to half inch thick, and to 5 broad generally. For rollng rods above ½ diameter they are 10 inches diameter with 90 revolutions. For producing steel from ½ down to ⅛th square and flats in proportion, 8 inches diameter, with from 155 to 217 revolutions. For sheets for shovels, pens, &c., &c., 14 to 16 inches diameter, with 30 to 33 revolutions, and rolls of 22 inches diameter, 12 revolutions.

All steel for tools, chisels, taps, dies, and for purposes where a cutting edge is put upon it is hammered. Files are an exception to this rule. The advantages of hammering over rolling, as far as regards quality, are manifest, the steel being rendered sounder and much denser, and, therefore, better capaple of standing any trying work it is put to Rolling can be done much cheaper, than hammering, and longer bars are obtained; when the purpose the steel is for will admit of its being adopted it is always preferred, the surface being more regular.

Next to this country the principal markets for the Sheffield manufacturer are the United States, Canada, and the Continent. In consequence of the increasing railway communication in India and Australia, the exports of steel and springs are becoming very great to these countries.

The United States and Canada consume large quantities of shovel, axe, and spring steels. The principal axe and shovel manufactories in the former country are on a most gigantic scale. The axe steel is sent out in bars about 1¼ × ⅝ and 1½ × ½, and the shovel steel in sheets, out of which the shovels are cut. Various attempts of late have been made to manufacture steel in the United States but all have as yet uniformly failed to accomplish it successfully. They have many difficulties to contend against, the want of a good coal and coke specially adapted to the conversion and refining of steel being the principal.

The most novel purpose to which steel has been applied of late years, and which has called forth so many various comments, has been found in the adornment of the persons of the fair sex,

EXPERIMENTS UPON WROUGHT IRON.

Number of Experiments		SECTION.				ELONGATION.									Per centage of Elongation.	Breaking weight in Tons	Breaking weight per sqr. inch.	Strength compared with No. 1	Section of Fracture.			
						TONS.																
		Length.	Width.	Thickness.	Area.	3	4	4½	5	5½	6	6½	7	7½	8					Width.	Thickness.	Area.	
1	Homogeneous Iron, No. 3	5¾	5/8	2/8	.234	....	....	....	....	....	....	....	....	½	....	8. 6	8	34.13	1	½	3/32	.141	Hom. Metal No. 3 hardens well.
2	Homogeneous Iron, No. 3	5¾	5/8	2/8	.234	....	....	....	⅛	....	3/16	7/16	5/8	1½	....	29.09	8	34.13	1	2/8	¼	.094	
3	Homogeneous Iron, No. 2	5¾	5/8	2/8	.234	....	....	....	1/16	3/16	9/32	9/8	5/8	1	....	17.74	7½	32. 0	.9379	15/32	¼	.117	
4	Homogeneous Iron, No. 2	5¾	5/8	2/8	.234	....	1/32	....	3/16	¼	7/16	9/8	5/8	1¼	....	21.74	7½	32. 0	.9376	7/16	¼	.109	
5	Homogeneous Iron, No. 1	5¾	5/8	2/8	.234	....	1/8	¼	2/8	½	4/4	2	....	....	....	35. 0	6½	27.73	.8125	7/16	3/16	.082	
6	Low Moor Iron	5¾	5/8	2/8	.234	....	1/16	3/16	5/16	½	1 2/8	....	....	....	....	23. 9	6	25. 6	.7530	½	2/16	.141	
7	Low Moor Iron	5¾	5/8	2/8	.234	....	1/8	3/16	2/8	5/8	1	....	....	....	....	17.74	6	25. 6	.7530	½	5/16	.160	
8	Northampton Iron	5¾	5/8	2/8	.234	....	3/16	5/16	9/16	1	....	....	....	....	....	17.74	5½	23. 5	.6885	9/16	5/16	.175	
9	Northampton Iron	5¾	5/8	2/8	.234	1/32	5/32	5/16	5/8	1½	....	....	....	....	....	21.74	5½	23. 5	.6885	....	....	.....	
10	Northampton Iron	5¾	5/8	2/8	.234	....	¼	2/8	11/16	1⅛	....	....	....	....	....	19.56	5½	23. 5	.6885	½	¼	.125	
11	Staffordshire Iron (Page's)	5¾	5/8	2/8	.234	⅛	¼	...	...	....	....	....	....	....	....	4.34	5	21. 3	.6240	....	....	.....	
12	Staffordshire Iron (Page's)	5¾	5/8	2/8	.234	...	3/16	....	....	....	....	....	....	....	....	3.26	4½	19. 2	.5626	....	....	.....	
13	Staffordshire Iron (Page's)	5¾	5/8	2/8	.234	....	¼	...	....	....	....	....	....	....	....	4.34	4½	19. 2	.5626	....	....	.....	

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ction of racture.		
Thickness.	Area.	
$\frac{3}{32}$	.141	Hom. Metal No. 3 hardens well.
$\frac{1}{4}$	.094	
$\frac{1}{4}$	.117	
$\frac{1}{4}$	.109	
$\frac{3}{16}$	.082	
$\frac{9}{16}$	.141	
$\frac{5}{16}$	.160	
$\frac{5}{16}$	.175	
....	.....	
$\frac{1}{4}$	.125	
....	.....	
....	.....	
....	.....	

The high price of steel has always been the obstacle to its more extensive use in the arts. Many have been the attempts to discover a quicker and a cheaper mode of producing it, resulting in failure in almost every instance when tried upon a large scale. Why have these failures taken place? Is it impossible to arrive at once at good steel by extracting from the pig the superabundance of carbon, without, as in the present mode of purifying the iron as much as possible and then making it reabsorb carbon? These are questions for discussion, Bessemers's and Uchatiu's patents have come to a standstill, not from the want of attempts to make them succeed. Piepe's process, it is now thought, is the only one that is going to work such a marvellous change in the iron trade of this country. The "Puddled Steel," as it is called will, on account of being cheaply produced, supersede the use of iron to a great extent. It has begun to do so in shipbuilding. But these are processes I must leave to a future time, not being fully prepared at present to enter upon them.

Another modification of cast steel has of late years interested many who have a practical interest in the use of the metals.—I allude to what is now generally known as "homogeneous metal." This metal is made by a process similar to that of cast steel, being perfectly homogeneous, at the same time possessing all the ductility of the finest charcoal iron and, to a great extent, the tenacity of steel. From recent experiments of this metal as compared with Low Moor, Northamption, and Staffordshire irons, I find the results all in favour of the homogeneous metal,—as the accompanying table will show:—

It will be obvious from the foregoing details of the manufacture of steel that in consequence of the great care that has to be bestowed, the large per centage of waste that takes place, and the high price paid for the materials, that steel of good quality cannot but maintain a high price, and, therefore, a limit is placed upon its application. We are striving to introduce all the improvements that can be done with safety, whereby the price may be reduced, but hitherto little success has attended our efforts. Still we do not despair, but confidently expect the day will arrive when the finer qualities of steel will be traded in in a more wholesale manner than they are at present.

We must, therefore, in the meantime be content to pay a fair price for good steel. The best that can be made is invariably found to be the cheapest in the end.

It being now Four o'clock,

The PRESIDENT said that the time they had allotted for business had terminated, and the paper just read was of such an important character that it was deserving of careful discussion, especially the portion relating to Puddled Steel. No hasty opinions ought therefore to be given, and he would suggest that the discussion be postponed.

Mr. TOOGOOD proposed that the discussion should be adjourned to the next meeting.

Mr C. JAMES, JUN., seconded the motion, which was carried unanimously.

Mr. BROUGH moved a vote of thanks to Mr. Wilson for his interesting paper. The subject deserved the most serious consideration of this Institute, as it was possible it would introduce a great alteration in the manufacture of iron.

Mr. KIDD seconded the motion, which was unanimously agreed to.

The Meeting then separated.

PROCEEDINGS.

22ND JULY, 1859.

The Annual General Meeting of the Members was held at the Royal Institution of South Wales, Swansea, on Friday, 22nd July:

MR. E. ROGERS, the President, in the Chair.

The Minutes of the last Meeting were read by the Secretary, and confirmed.

Messrs. Kelberer, Huxham, and Riley, were appointed a committee to open the Voting Papers, and to ascertain the result of the elections.

On the motion of Mr. COX, seconded by Mr. R. H. RHYS, it was agreed to cancel rule 31, and to substitute the following:—

"Application for admission of a candidate as Member, Associate, or Graduate shall be made, in writing, by a member of the Institute, accompanied by the recommendation of another member. The applicant shall be balloted for in such manner as the Council shall from time to time direct; and he shall be elected if the majority of the recorded votes be favourable."

SOUTH WALES INSTITUTE OF ENGINEERS.

Treasurer's Account, July 22nd, 1859.

1858.	Receipts.	£	s.	d.
July 21.—By Balance		158	0	8
1859.				
July 22.— " Cash received from 84 members		194	5	0
" " Cash received from 6 graduates		6	6	0
" " Interest		3	14	6
		£362	6	2

1859.	Expenditure.	£	s.	d.
July 22.—To Secretary, one year's Salary to 22nd July, 1858		50	0	0
" " Advertising		2	3	3
" " Printing and Stationery		74	6	8
" " Engraving		140	3	3
" " Hire of Room		1	0	0
" " Incidental Expenses		10	5	2
" " Secretary, one year's Salary to 22nd July, 1859		50	0	0
		£327	18	4
	Cash Balance	34	7	10
		£362	6	2

1859.				
July 22.—By Cash Balance		34	7	10
" " Members' Subscriptions due		149	2	0
" " Graduates ditto		3	3	0
	Available Balance...	£186	12	10

1859.				
July 22.—To Cash in the hands of Messrs. Wilkins and Co.		21	10	10
" " Cash in the hands of Treasurer		12	17	0
" " Subscriptions due		152	5	0
		£186	12	10

Coal Mines; and, in 1856, was admitted a Fellow of the Geological Society; and elected a member of the Institute of Engineers in the same year. He was an honorary member of the Newcastle Institute of Engineers. He died at Clifton, on the 13th of July, 1858, aged 34.

Applications for admission as members still continue to come in, and the Council expect a considerable increase of numbers during the forthcoming session.

The financial position of the Institute will be seen by the accompanying Treasurer's Statement:—

The Chairman announced that the Ballot Lists had been opened by the Committee, and that the following Office-bearers were elected for the session 1859-60:

President:
Mr. W. S. Clark.

Vice-Presidents:
Mr. W. Menelaus
" L. Brough

Council:
Mr. John Cox
" R. Bedlington
" G. Martin
" G. C. Greenwell
" A. Bassett
" R. H. Rhys
" M. Fryar
" G. Fisher
" F. Levick, Junr.
" D. Roberts

Treasurer:
Mr. E. Brigden

Secretary:
Mr. E. Williams.

Mr. H. J. Evans and Mr. J. W. James were appointed Auditors to examine the accounts presented by the Treasurer.

The PRESIDENT then addressed the meeting.—He congratulated them upon the success of the Institute and the prospects they had before them of accomplishing the aim for which they met together; the report of the Council gave them full information as to the working of the Institute. The question had often been asked, by strangers and friends—What is the use of these Institutes? What shall we benefit if we avail ourselves of them? Are they of any special use for our progress and every-day work? Do they tend to elevate us individually, and as a nation? And, do they benefit

humanity? These many questions cannot be replied to fully here, but the work we are trying to do, and the ultimate success, of which we do not doubt, may be shortly summed up. *The object of this Institute, and such associative bodies, is, by interchange of opinion and experience, to educe from the learning and facts we may individually acquire, science and wisdom; which, when applied, may benefit humanity.* Our attention is principally confined to one branch of science, viz.: the natural laws which govern the production and use of the metals, and more especially, *Iron;* but, as every branch of science is more or less dependant on others, and there can be no perfect separation of any part of the whole, we are thus led to the study of Geology and Mining, and other collateral branches of science, as influencing almost every department in our own more immediate profession. The vegetable fuels we use as coals, are the results of light and organization; and countless ages since, lived, were buried, and protected for us; now to be utilized by their decomposition. The light and heat given by the Great Power to former creations, we now by science again eliminate, for our use, and make the ready servants of our wants and wishes. The Iron Ores have been some thrown up, through fissures in the crust of this planet, from unknown depths; and, after undergoing chemical decomposition, have been deposited in different forms; others have been secreted by countless millions of Infusoria from iron dissolved in the seas they lived in, long before man had his existence on this globe. The original position and levels, as also the chemical character of these materials, are greatly altered since the period of their formation, and prove that constant changes have ever been going on upon this sphere. The economic working and use of these materials greatly depend upon a knowledge of the laws by which such changes were effected. As in the physical, so in the moral world; there is no stagnation, no standing still: in every part of our life we are the means of either pulling up those we associate with to our standard, or they are drawing us down to theirs. This important fact will teach us the value of educating all those around us; we elevate and protect ourselves, nationally and individually, by sound education; true science and wisdom bless

him who gives and him who takes * By education we do not mean *learning* only: *the words* LEARNING; SCIENCE; *and* WISDOM; *are too often treated by us as one and the same*, and used as convertible terms:—*Learning* implies only "skill in letters,"† or the "power of imitation."§ A great mass of accumulated facts, without the *knowledge*‖ how to use them, is useless to society. We will not discuss this subject here, to shew how want of attention to this truth injuriously influenced, for centuries past, our University education; the fact is admitted, and the necessary reforms are in progress. The *confusion of learning with science, and the successful attempts often made to pass the former off as science, upon men too deeply occupied by incessant work in special pursuits to notice either closely*, had led to an idea or opinion, that men of science were not practical.—This opinion is entirely incorrect; *true science, from its nature, must always be highly practical.* The progress of civilization and productive industry, in other countries where science has been more carefully applied, we find by experience, is undermining our position as a nation; but we seem now to be aroused to a sense of the danger. In defining *science* we use the words *knowledge and understanding* as correlative terms: by them we mean "certain perception," "indubitable apprehension."‡ *The great importance of a knowledge of the laws of nature, in their application to our manufacturing and industrial pursuits*, is now believed by all as *a truth:* and its important bearing upon our resources, and, perhaps, *our existence as a nation*, is acknowledged. The extent of the laws which govern our being here, is such that no human intellect can be perfectly conversant with all; hence, the necessity of what we now term "special scientific knowledge," or the "division of labour." Examples of this we find in the division

* "There is that scattereth, and yet increaseth; and there is that withholdeth more than is meet, but it tendeth to poverty."—Prov. 11, c. xxiv-v.

† Johnson.

§ "In imitation of sounds that man should be the teacher is no part of the matter, for birds will *learn* one of another."—*Bacon's Nat. His.*

‖ "Ignorance is the curse of God;
Knowledge the wing wherewith we fly
To heaven."—*Shakspeare.*

‡ Johnson.

of work, as taken by different Scientific Societies, and in our works and manufactories the same principle is constantly progressing; we have, as a nation, recognized its importance in the establishment, by the Government, of Schools of Mines, and of science applied to the arts, where different branches of science are specially taught, and some of the most noble and ablest men of our age have spent their lives in training those who are to direct and influence the future industrial position of our country. Sir John Herschel has summed up very accurately the use of science. "If the laws of nature on the "one hand, are invincible opponents, on the other, they are irresist- "able auxiliaries; and it will not be amiss if we regard them in "each of these characters, and consider the great importance of a "knowledge of them to mankind,"

I.—"In showing how to avoid attempting impossibilities."

II.—"In securing us from important mistakes in attempting "what is in itself possible, by means either inadequate or actually "opposed to the end in view."

III.—"In enabling us to accomplish our ends in the easiest; "shortest, most economical, and most effectual manner."

IV.—"In inducing us to attempt, and enabling us to accomplish, "objects, which, but for such knowledge, we should never have "thought of undertaking."

Wisdom.—"The power of judging rightly; the knowledge of "divine and human things;"* *the highest faculty which God gives to man, and where given, a most sacred trust. No great discoveries in science to benefit humanity, seem ever to have been made except by men who held this perceptive faculty.* Professor Owen has well remarked, "It is no light matter, therefore, the work that "we are here assembled to do. God has given to man a capacity "to discover and comprehend the laws by which His universe is "governed, and man is impelled by a healthy and natural impulse "to exercise the faculties by which that knowledge can be acquired. "Agreeably with the relations which have been instituted between "our finite faculties and the phenomena that affect them, we arrive

* Johnson.

"at demonstrations and convictions which are the most certain that "our present state of being can have or act upon. Nor, let anyone "against whose prepossessions a scientific truth may jar, confound "such demonstrations with the speculative philosophies condemned "by the Apostle; or ascribe to arrogant intellect, soaring to regions "of forbidden mysteries, the acquisition of such truths as have "been or may be established by patient and inductive research. "For the most part, the discoverer has been so placed by circum-"stances, rather than by predetermined selection, as to have his "work of investigation allotted to him as his daily duty; in the "fulfilment of which he is brought face to face with phenomena "into which he must enquire, and the result of which enquiry he "must faithfully impart. The advance of natural as of moral "truth has been and is progressive; but it has pleased the Author "of all truth to vary the fashion of the imparting of such parcels "thereof as He has allotted, from time to time, for the behoof and "guidance of mankind. Those who are privileged with the fa-"culties of discovery are, therefore, to be regarded as pre-ordained "instruments in making known the power of God, without a know-"ledge of which, as well as of Scripture, we are told that we shall "err."* *Let us encourage and help each other to do our work here in earnest, truthfully and wisely, humbly depending on the guidance of the Great Author of All,* "for in him we live, and move, and have our "being."

The Meeting was then adjourned to eleven o'clock Saturday morning.

SATURDAY, JULY 23RD, 1859.

The Members assembled this day at eleven o'clock,

Mr. E. ROGERS, the President, took the Chair, and, in opening the proceedings, remarked that the election of officers and the ordinary business of the Institute having been concluded yesterday, they had now to read and discuss various papers, some of which had been in arrears for some months. Without making further observations, he would call upon the Secretary to read the first paper;—

* Address to the British Association, Leeds, 1859.

ON RAILWAY WHEELS.

By Mr. JAMES MURPHY.

DESCRIPTION OF WHEELS GENERALLY USED ON RAILWAYS, WITH THE VARIOUS IMPROVEMENTS MADE FROM TIME TO TIME WITH A VIEW TO INCREASED SAFETY, DURABILITY, AND ECONOMY.

A GREAT variety of railway wheels have been brought forward as inventions and trials on the different railways, many of them shewing great mechanical ingenuity; the total failure of some, and partial use only of others, have all been useful as lessons to practical men, who have built their experience upon their faults and failures. In attempting a short description of railway wheels in general use in this country, I have selected as illustrations many which have stood the test of working; others to illustrate schemes of merit in themselves, but wanting the aid of more practical men than the inventors, to render them useful.

In considering a wheel as a piece of mechanism, it may be said that the introduction of wheels into any country has advanced its material prosperity in an extraordinary degree, and, apart from Christianity, appears to be the forerunner of civilization, commercial enterprise and wealth; at the same time aiding, unfortunately, in carrying on desolating wars.

When man discovered the utility of employing animals to aid him in his wants and labours, he found the horse best adapted to his purposes, and on reducing him to obedience, the invention of

wheeled war chariots followed. Referring to the sacred volume we learn that horses and chariots are mentioned the first time when Joseph went from Egypt carrying his father's remains to Canaan. "There went with him chariots and horsemen." It is related that Sesostris had 27,000 chariots of war, and we further learn that the honour of subduing the horse, and the use of wheeled chariots, is due to the Egyptians. Homer describes the use of horses and chariots at the siege of Troy, stating that "King "Priam rode into the Grecian camp in a beautiful new built "travelling carriage, while the treasure was carried in a four "wheeled waggon;" and, in describing Juno's imaginary car, says—"Hebe fastened on the wheels to the iron axles; these "wheels had eight brazen spokes, the felloes were of gold, and "the tyres of brass."

Considering that this was written about 900 years before the introduction of Christianity, with the exception of the particular materials, we have a description of a wheel very similar to those in use on railways at present, comprised by eight spokes, felloes, tyres, and axles; as no mention is made of a separate nave or boss, I presume Vulcan had a perpetual patent for forming a boss by the elongation of the spokes, and we may yet hear of a thunderbolt action against Henry Smith for an infringement.

It may readily be asked what improvements have been made in wheels for a period of thirty-three centuries. The principle is the same in application, and very nearly in manufacture, as far as road carriages are concerned; the wheels at that remote time revolved freely on their axles, but in railway wheels we have gone back to a contrivance which would suggest itself to a New Zealander—that of using a common roller; for removing the obstacles that presented themselves to his passage through the woods; and were it not for its clumsy appearance, a complete cylinder with a spindle through the centre, like a garden roller might be used instead of a pair of railway wheels.

The history of wheels since they were first made would form a very interesting subject for a paper, and I cannot be considered as

trenching upon such a subject in attempting to describe railway rollers, for rolling stock.

The introduction of passenger traffic on tramroads and railways rendered it necessary to make the transit over them safe and expeditious, and next to the stability of the permanent way as one part of the machine, the rollers or wheels and axles were of equal importance as another. Numerous suggestions for additions and improvements have been invented and patented; many have been tried; but comparatively few have stood the unfailing test of wear and tear. The designs were generally directed to render them light and safe; and almost every material, even sand and sawdust have been employed to cure the defects alleged to exist. The several varieties are known either by the materials employed, or or the names of the inventors, such as cast, wood, plate, compound, and wrought iron wheels; Sharp's, Hadden's, Cottam's, Gibson's, Beattie's, Smith's, and several others. Some of these inventions are confined entirely to the improvement of the skeletons of wheels; others, more particularly to the importance of making the tyre so perfectly secure as to render it impossible to leave the skeleton in case of fracture.

One of the earliest patents for railway wheels was granted to George Hawks in 1807, for "A method of making and likewise "keeping in repair cast iron wheels for coal waggons, and other "carriages, where such wheels are applicable." This refers to cast iron wheels alone, no mention is made of wrought iron, and the proposed improvements were intended to remedy the defects then found to exist by the unequal contraction of the metal in cooling, by constructing the wheel in several parts, and bolting or rivetting them together; also with a view of replacing the tyre when worn out.

Up to 1816 no progress appears to have been made. In that year Messrs. Losh and Stevenson took out a patent for a wheel with wrought iron arms cast into the nave, and dropped into dovetail mortice holes in the rim, the arms being heated previous to dropping them into the holes, and afterwards keyed up. Another

method was to make cast iron spokes curved like an elongated S, leaving an opening in the cast iron felloe, over which was shrunk a wrought iron band to form the tread of the wheel, the flange being on the cast iron inner rim.

The first wheels used on horse tramways appear to have been entirely cast iron, the speed on which did not exceed three miles an hour; subsequently cast iron wheels were introduced on railways where locomotives were used, and higher speeds attained. They have gradually disappeared, and are seldom used except in connection with a wrought iron tyre. Cast iron wheels are used extensively in America; they are made, it may be said, solid—that is, the nave, spokes, or plate and tyre in one piece, the centre between the nave and tyre is sometimes made undulating, concave, or corrugated, running sometimes concentric with the nave. These contrivances are intended to neutralize the effects of cooling as well as the extremes of temperature, and enable the makers to produce wheels more uniform in the strains on the different parts of the wheel, and consequently less liable to fracture in work.

Breakages of wheels take place frequently, but the effects from accidents of this sort are not felt so injuriously there as in this country, owing to the use of eight wheels under every passengers' and baggage car, running at speeds under thirty miles an hour. These eight wheels are used in sets of four attached to a frame nearly square, called a "bogee;" two of these frames are placed under a long carriage. These bogees are used extensively under mineral waggons, and are perfectly safe on the quickest curves. The general quality of American cast iron used in wheels is tougher and stronger than British. Chilled cast iron locomotive tyres are used frequently, but owing to the difficulty of putting them on and securing them, wrought iron tyres from this country are being substituted, and are likely to supersede them.

So little interest is attached to cast iron wheels, since they have been uniformly condemned on nearly all passengers' lines in this country, that a complete description of the several varieties that have been proposed would scarcely repay the time of perusal.

Truscott's American wheel, described in the "Franklin Journal" for January, 1839, is made thus: the tyre is of the ordinary shape on the tread and flange, and connected with the nave by two convex parallel cast plates; six or more circular openings are left in both plates; the spaces between the plates are as usual cored out. The wheel complete is one casting; in this case the convexity of the plates allows for contraction or expansion of the metal. Another variety is made by placing concave plates opposite each other instead of parallel. One-half of the nave only is in this case attached to each plate, making a further provision for expansion or contraction. This plan of wheel, with slight modifications, is in general use in the United States.

Mr. Greenhow proposed to dish the spokes, as in a road waggon, and use a hollowed surface on the tread of the tyre.

The most successful cast iron wheels were made by Sharp, Roberts, and Co. These were constructed with, say, ten spokes, formed with a rib on each angle in section, or in the shape of a cross. Mr. Roberts states, "The wheels are so carefully proportioned in the several parts, that they are not injured in cooling." The skeleton or felloe is turned to receive the tyre, which is put on in the usual manner. They made another modification of this wheel in 1846; the spokes were formed with a double web, like letter T. The outer rim or felloe had the web on one side; the flange of the wrought iron tyres being placed on the opposite side. Wheels on this plan have been successfully constructed to five feet diameter. The increased weight being rather an advantage for locomotives. One of the latest of this class was invented by Mr. Alfred Krupp, of Prussia (Fig. 1). His plan was that of a solid cast iron disc, including the nave, corrugated, or otherwise. These radial, or undulating corrugations, diminish in depth towards the rim, which is furnished on each side with a flange to receive bolts for securing the tyre, which may be of wrought iron or steel shrunk on, or put on cold by hydraulic pressure. None of these wheels have come under my personal observation.

In 1830, Mr. William Losh brought forward a wheel (Fig. 1.

A) which for sound principle, ingenious mechanical detail, facility of execution, and durability, has not been exceeded by any wheel having a cast iron boss. In describing the mode of making this wheel, he says, "The spokes are made by bending a bar of "iron into the shape shewn in the drawing, the central nave "is of cast iron, and the wrought iron spokes are provided "with elbow bends near the middle of their lengths, the pro- "longation beyond these elbows being curved, so that when "the proper number of such spokes are put together their "curved prolongation between the elbow bends form a com- "plete circle, and the straight parts within their elbow bends form "the radii of that circle." The cast iron forming the nave is run around the inner ends of all the spokes, which had previously been indented to prevent them drawing out of the nave. This forms the skeleton or inside, the tyre is then put on in the usual manner, and rivetted. Modifications of this wheel have been made, such as instead of the spokes being placed back to back they are equally spaced all round the boss (Fig. 2). The spokes are sometimes welded together on the outer side, forming, as it were, a complete wheel before the tyre is put on, as at *a a a* Fig. 1.

About this time, Mr. Winams, of North America, patented the introduction of what he called "Anti-friction wheels" in place of fixed bearings for the axles. This was intended to apply to common road wheels particularly; another part of this invention relates to the conical form of the running part of the tyre, in order that, he states, "on such parts of the line of railway as may be curved the "larger diameter of the wheel on one side may run upon the "extended line of curve, whilst the smaller diameter of the oppo- "site wheel may pass along the shorter line, or lesser curve." Whatever may have been the previous practice, this is the first mention made with reference to the utility of the conical form given to tyres; adding so much to the general safety of rolling stock on railways. The practice of coning the wheels of heavy waggons on common roads had been general many years previous to this date, but for a different purpose. It is not necessary here to enter minutely

into the reasons for coning wheels for road carriages, further than to show to what an injurious extent the practice was carried, so as not only to increase the draught, but to destroy the road.

The principle of dishing a wheel generally adopted rendered it necessary to incline the axle arms, so as to bring the underspokes carrying the load perpendicular. When greater loads were to be carried the strength of the wheels and axles were increased, and the widths of the tyres were proportioned to the load, as required by turnpike acts, but which in other countries is public law. Wheels having twelve inches width of tyre were not uncommon in the West of England, the angle made by the arm of the tyre (rendered necessary by the dishing of the spokes) involved the necessity of coneing the wheel, and in many cases making six inches difference between the inside and outside diameter; it is evident in this instance that the inside of the wheel would travel nineteen inches further than the outside at each revolution, or a distance of nearly 310 yards in one mile of road; the smaller diameter being dragged forwards grinding away part of the tyre and road: proving the gross absurdity of placing a coned wheel in contact with the road for the whole width of the tyre. Wheels thus made would travel freely round a curve of 20 to 30 feet radius, but not in a straight line.

The same injurious action would take place with railway wheels if the rails were wide enough to take the whole width of the tread of the tyre, nevertheless, a somewhat similar grinding action takes place in railway travelling through the difference in diameter of those parts of the tread of the tyre in contact with the rail; this is particularly observable where the flanges are much worn, or the rails wide to guage; one wheel travelling sometimes on its smaller, at other times on the larger diameter, next the flange; in either case one wheel would travel further than the other according to the difference of circumference in contact with the rail, and must consequently be dragged to that extent. The conical form given to the tyre enables the wheels to travel round curves with greater ease, while on a straight line it seems to steady

them. The radii of curves, and speed of trains vary so much, that the usual taper, or cone of the tyre, is not sufficient on sharp curves to prevent the outside flange grinding against the outer rail; therefore, it is found of great advantage to raise this higher than the inner rail, proportionably to the radius and speed, to the extent, in some cases, of nine inches.

The tendency of a coned wheel when running on a rail is towards its largest diameter, consequently, a pair of wheels similarly coned, each dragging in opposite directions, counteracts in a great measure the tendency to run off on one side or other. On the same principle as a strap, running over a double coned pulley, has when in motion, a constant tendency towards the largest diameter.

In 1831, Mr. George Stephenson proposed to make wheels with eight oval tubular spokes or arms, to be filled with sand, the nave was cast or keyed on the inner ends, and a rim cast or rivetted on the outer ends, over which was rivetted the flanged tyre; for large wheels the number of spokes was increased, one-half the number being dished towards one side of the nave, and the intermediate half alternately to the other side, to increase lateral strength. This mode of making locomotive wheels was much used before the introduction of solid wrought iron bossed wheels. Another system was at this time brought forward by W. B. Hick, which was called "the plate wheel." The nave was made of cast iron, and instead of spokes radiating from the centre the whole space between the tyre and boss was made solid by two discs of plate iron rivetted to the tyre. This was followed on the same principle by Van Wart, who first formed a wheel with spokes, and then plated them on each side, with discs rivetted to the spokes on each edge. Hague followed, who proposed to rivet the wrought iron discs to an inner tyre, and cast the boss on the plates. Four feet plate wheels were much used about fifteen years since, but have failed to warrant their continued use.

In 1837, Mr. G. Cottam brought forward a wheel constructed with the ends of the flat spokes welded or bolted to a flange rolled on the inside of the tyre (Fig. 3), the spokes being cast into a

centre nave as usual. These have not sustained their place. Messrs Swaine and Bovill constructed wheels on the same principle, with the addition of a double flange on the inside of the tyre (Fig. 4) between which the spokes, (which were enlarged at the ends,) are welded. This class of wheels are very subject to become loose between the spoke and the tyre, when subject to great speed and heavy loading. The tyre being thinnest on the tread of the wheel, where it is liable to the greatest wear, and on becoming much worn, is liable to split open by the obtrusion of the spoke ends, in this state these cannot be repaired with any advantage.

That which is known as Haddan's bent spoke wheel (Fig. 5) is a modification of Losh's; the intention was to produce something different, in doing so the principle was disregarded by removing the continuous support for the whole of the tyre. Although the tyre was supported at more points of the circumference, it was impossible to secure the outer part of the spokes without the application of a separate ring secured to the spokes, over which the running tyre was proposed to be secured; this increased the number of pieces composing the wheel, without a corresponding benefit; these do not maintain the character first obtained for them, and although they did good service on many lines, they have given way to a better form of spokes.

Fig. 6 represents a wrought iron wheel with a cast iron boss, and differs from the principle of Losh's wheels only in the shape of the section of spokes, which has a rib shewn at *a a a*, and is known as the "fancy spoke" wheel. This shaped spoke forms a strong wheel, and consequently the spokes are seldom welded. Having been used in the first instance by Sir John Mac Neill on his Irish lines, it is known by makers sometimes as the "Irish wheel."

Fig. 7 is a wheel with single wrought iron spokes, and cast iron boss; the spokes are tapered in section from the boss towards the rim. These spokes are usually welded on to a straight bar, which is to form the rim or felloe. It is then bent to a circle; the boss cast and rim welded. It is then turned to a given diameter, and the

tyre put on as directed. This form of wheel is sometimes made by bending a bar of iron to form one spoke and part of the felloe or rim to its junction with the next spoke; all these junctions are then welded up, the boss cast, and wheel finished as usual.

Fig. 8. This is one of a class of wrought iron wheels; the boss being formed by a junction of the spokes, on each side of which is welded rings to give the boss the required width. The spokes for these wheels are hammered or rolled in bars, with the enlarged portions to form the boss, shewn on Fig. 9. The bars are then bent to form spokes, which being laid together form the interior of the boss *a a;* rings welded on *b b.* These wheels are lighter to the extent of 50 to 60lbs. each, which constitutes one advantage over cast iron bosses or wood wheels. The utmost skill and experience is necessary to make these wheels sound in the boss during the process of welding; failures in this respect are very numerous, and if the weldings are not complete this class of wheels are exceedingly dangerous, and impossible to repair with advantage.

Fig. 10 represents a single spoke wrought iron boss wheel. The mode of forming this is similar to Fig. 7, with the substitution of a wrought iron boss for cast. The ends of the spokes must in this case be shaped to form a proper junction at the boss; side rings are then welded on; and the wheel finished in any way specified.

Fig. 11 is a solid wrought iron crank boss engine wheel, consisting of eighteen spokes. The process of making is similar to the single spoke wrought iron wheels, and when properly made may be considered the most superior specimen of wrought iron work that can be produced at the present day. These wheels are made perfect up to 8 feet diameter.

Figs. 12, 12*a*, 12*b*, represent the invention of Mr. Henry Smith; the models also represent wheel bosses made according to principle of the patent. The object intended is to dispense with the necessity of welding wrought iron spokes at the boss, by forming

them out of a solid bloom by hydraulic pressure in moulds. It is calculated to take a pressure of 1600 to 2000 tons to produce a solid boss with the arms or spokes sufficiently long to be lengthened by welding. The perfection of such a mode of manufacturing wrought iron wheels will render them much safer and cheaper than at present, and if successfully formed will probably supersede the present wrought and cast iron bossed wheels.

Some very excellent wheels have been constructed by a combination of wood with cast and wrought iron. The principal object sought was to prevent as far as possible the noise produced by wheels made entirely of iron, when running. That known as Beattie's (Fig. 13), made by Lloyds, Fosters and Co., is an excellent wheel, and one of the best of this variety. The nave is of cast iron, having upon its periphery a number of mortices into which are driven segments of wood, with the grain in the direction of the radii of the wheel. The inner end of these segments abut against the periphery of the nave, and against pieces of wood placed in the bottom of the mortices. Wooden wedges are driven between the inner ends of the segments. An inner tyre with a flange on it, and small flanges on its inner circumference, is then shrunk on the end of the wooden segments. This ring is turned slightly conical to receive the outer tyre, which may be of steel.

Fig. 14. Mansell's wood wheel is very similar in construction to Beattie's, with the exception of two retaining rings, which are dovetailed into the tyre, and secured to the wood centre by bolts. The boss is constructed with a loose face, or plate, which is laid on each side, and bolted through the wood to the boss. These wheels have been manufactured with great success by Lloyds, Fosters, and Co., and in the wear give satisfaction.

Fig. 15. Mr. Henry Smith constructed a wheel, by combining cast iron centres, wood felloes, and wrought iron tyres in such a manner that the wooden felloes are forced out by wedges, called Smith's patent expanding wooden wheel. The centre is cast iron

in one piece *a a*. The wood felloes, *b b b*, are made in segments equal in number to the spokes in the centre, and dowelled together in the manner of an ordinary road wheel. The tyre is pressed on by screws or hydraulic power, and bolted through the segment and centre. Angular pieces are placed at each joint, and forced against the segments with wedges, *c c c*, secured by nuts. The wood applied in this way, having the grain parallel with the work and pressure, however well pressed before being used, was liable to contraction; and however well protected, appears to have been acted upon by atmospheric changes.

A wheel similar in principle, called the Pimlico wheel, has a cast iron centre, having mortices to receive wooden spokes. The felloes are similar to the last described, dowelled in the same way, and having a wrought iron ring put on under the running tyre. Wooden spokes appear to be the peculiarity of this wheel, and when properly constructed would run easy and with little noise, but must be subject to similar effects in working as the last.

A large number of wheels were made, called "Hadden's wood wedge wheels." The spokes were formed of wrought iron, bent to form, in connection with a cast iron boss, the felloe, or a complete skeleton. Spaces were left between the spokes for the introduction of wooden filling pieces, larger at the boss end. The felloe was then welded up by the introduction of filling pieces, connecting the whole of the spokes. The wooden filling pieces were then pressed between the spokes, and driven outwards by wedges inserted between them and the boss; the tyre was then put on in the usual manner. These wheels, though a large number were made in the first instance, were not repeated to any extent. Another variety had the wedges or filling pieces reversed, having the largest near the tyre; these wedges were pressed into their places, and confined by the tyre, which was shrunk or pressed on. There are few, if any, of this plan now running.

A wood wheel, known as "Wharton's" (Figs. 16, 17, 18, 19), which has been running for many years on the London and North

Western Railway and contiguous lines, appears to stand its work as well as any of this variety; it will be observed by the sketch that one of the principal features of this wheel consists in a method of compressing the wooden blocks by bolts and wedges. A is the cast iron boss in two parts, bolted together by bolts E; the bolts C and iron wedges H confine the blocks in their circular beds. An inner tyre B, having double flanges, clip the blocks. The outer tyre is then put on, and bolted to the blocks by tapered bolts G, which are secured by keys. In putting this wheel together the cast boss is prepared with circular beds to receive the wood blocks, which are first turned circular. The bolts with wedge pieces are then inserted, and screwed up; after which the skeleton is put in the lathe, and segments of the blocks turned off to receive the inner ring, which is put on cold: the running tyre is then put on, bolted and turned up.

The principal objection to this wheel appears to be in the number of parts composing it, all liable to become loose; the additional weight also, like the wheels of this class, operates against their extensive adoption. They are considered, generally, safe wheels, and greatly diminish the noise in travelling.

Fig. 20 is a section of a tyre, shewing the mode of dovetailing the spokes into the tyre. I believe this was patented by Mr. Slaughter. A great many were made by Mr. Henry Smith for the Monmouthshire lines, and no instance of a loose tyre or bad wheel has occurred, though running upwards of ten years.

Fig. 21 is a mode of fastening the tyre to the skeleton, adopted by Mansell and Beattie. The tyre is bored out, and cut into a dovetail on each side of the tyre, into which are secured the outer circumferences of two wrought iron rings, formed with a corresponding dovetail. These rings are secured together by bolts passing through the skeleton. This is a very good mode of securing the tyre, although the number of parts is increased.

Fig. 22 was proposed as a security against the tyre flying off, in case of fracture; but is deficient in the absence of a stop, or a corresponding dovetail on the flange side of the tyre.

Fig. 23 represents Gibson's mode of securing the tyre.—The tyre being bored out, the fillet is dovetailed, a groove at the back of the tyre being cut out to a proper depth to receive a wrought iron ring *(d)*, shaped in section as shewn;—this ring is inserted in the groove after the tyre is put on. The fillet at the back, at *b*, is then hammered down at intervals to secure the ring. The skeleton must be turned with corresponding dovetails on outer edges *c c*. This is a sound and perfect mode of securing the tyre, in case of fracture.

Figs. 24, 25, 26 are sections of improvements made recently in securing tyres on the skeletons, by the author. By the method here adopted, the thickness of the tyre is increased about three-fourths of an inch over the ordinary tyre, still shewing the same thickness on edge of tyre, as compared with Figures 1A and 2. The tyre may be worn down much thinner than is usual, as it is impossible to spread or split longitudinally; and, having a wide surface in contact between the skeleton and tyre, contributes to the permanency of the wheel.

For passenger carriages running at great speed, it is of the greatest importance to secure the tyre, in case of fracture. Those which have been made on this plan are running well and have given satisfaction. It is nearly impossible that the tyre can become loose, or fly off in case of fracture. The object sought to be obtained in this case was to reduce the number of pieces or parts composing the wheel, namely, the skeleton and tyre; and these when in work may be considered as one piece.

The subject of axles is of equal importance to wheels, and fully entitled to form a separate paper, which may be forthcoming at a future day.

I thus feebly redeem my promise to furnish a wheel paper, and regret it is not more complete, but trust it will convey some information on a subject, on which so little is written or published; with the exception of the crooked and ambiguous descriptions attached to patent abstracts.

In closing this important subject, I may remark that I have endeavoured to shew the best examples of the different classes of cast, wood, and wrought iron wheels, with the best practical method of securing the tyre, in case of fracture, so that it cannot fly and cause the carriage to leave the line. Accidents of this nature are not now so frequent, owing to more extensive experience, increased skill and improved machinery used in wheel making, and the general tendancy of Railway Companies to encourage and adopt improvements in rolling stock. I can readily anticipate the time not far distant, when the present plan of reducing the strength of tyres 20 to 25 per cent. by drilling holes for bolts through them, rendering them so far unsafe, will be abandoned; and wrought iron wheels with steel tyres, put on by the improved modes of dovetailing, will be the rule instead of the exception, as at present. The increased expense in the first instance will be amply repaid by the doubly increased durability and almost perfect safety.

The Chairman said that this was an important subject, and the paper of Mr. Murphy was an original and a valuable one. In no Encyclopædia had any connected description of wheels been given. The subject not having been brought forward before, probably the best way would be to postpone the consideration of it to a future time. For his own part he should object to have such an interesting paper discussed at present; but, in suggesting its postponement, he would also ask that Mr. Murphy would be kind enough to fulfil his promise by giving them another paper on axles.

Mr. Murphy said it would be very easy to describe ordinary axles; but to write a paper thereon will involve further trials in extension of those already recorded: those would take some time, but he hoped to complete them next year.

Mr. T. Evans remarked that this was a most interesting subject, and proposed that a vote of thanks be given Mr. Murphy for his paper.

Mr. Brigden seconded the resolution of Mr. Evans, which was carried unanimously.

The CHAIRMAN said that the next paper was one of much local interest, and one which was new to most of them. It was written in consequence of some recent discoveries of iron ores which had been made in Wilts, Somersetshire, &c. Mr. Greenwell had been himself connected with the discoveries, and had perhaps taken a more active part in investigating the various ores than any other gentleman. He was, therefore, most competent to write such a paper.

The Secretary then read the following paper :—

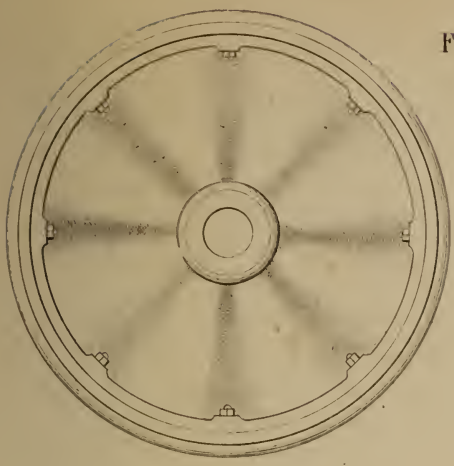

Fig. 1.

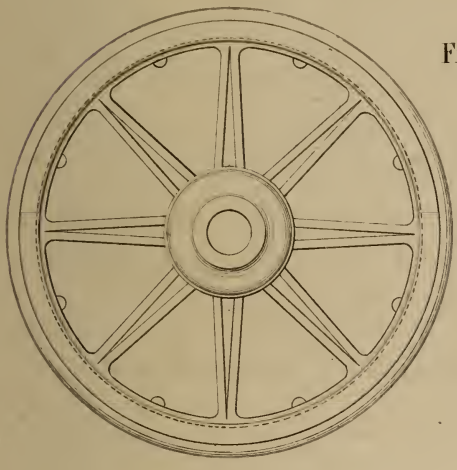

Fig. 1A.

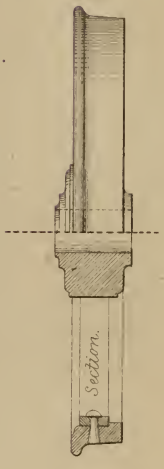

Fig. 2.

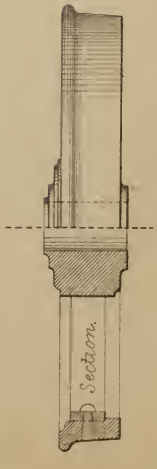

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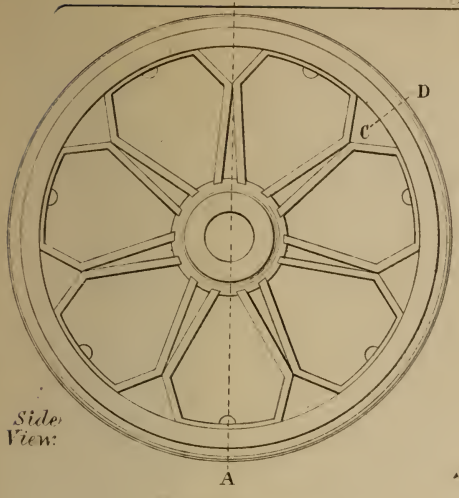
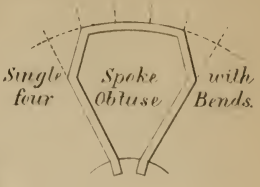
Fig. 5.





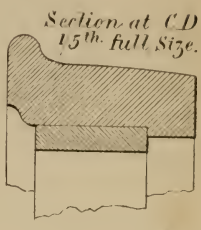


Fig. 6.

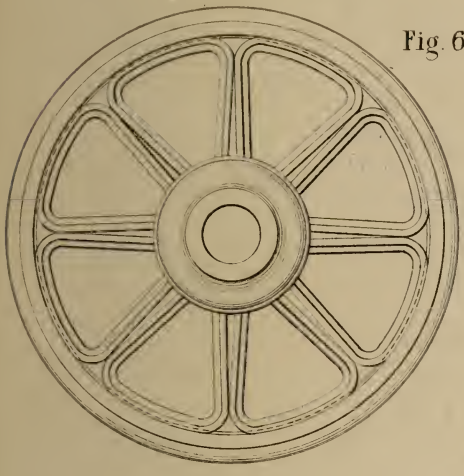


Fig. 3.

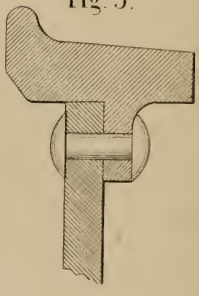


Fig. 7.

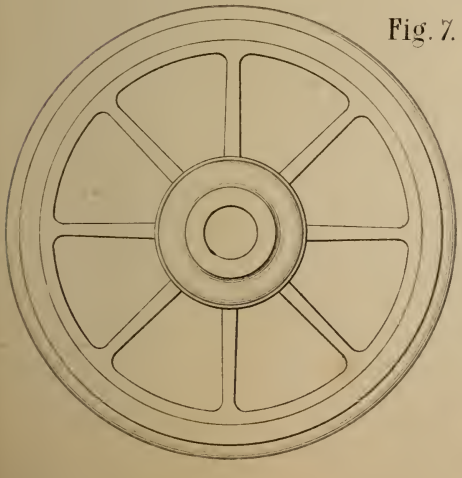


Fig. 4.

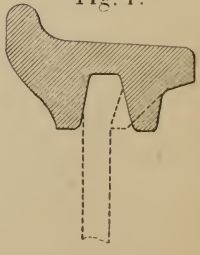


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Fig. 8.

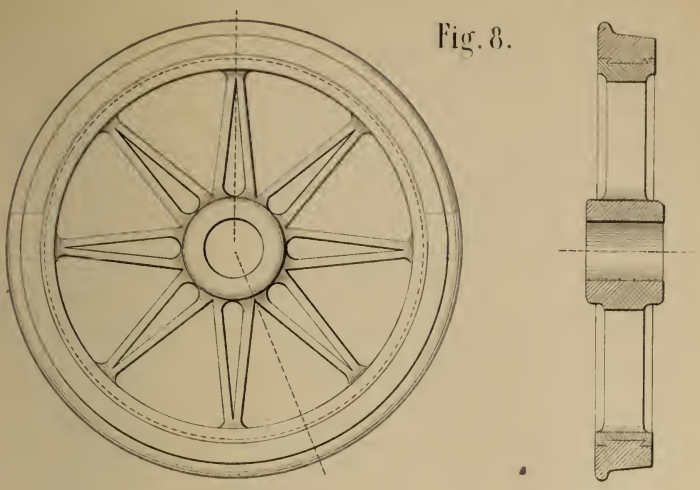


Fig. 9.

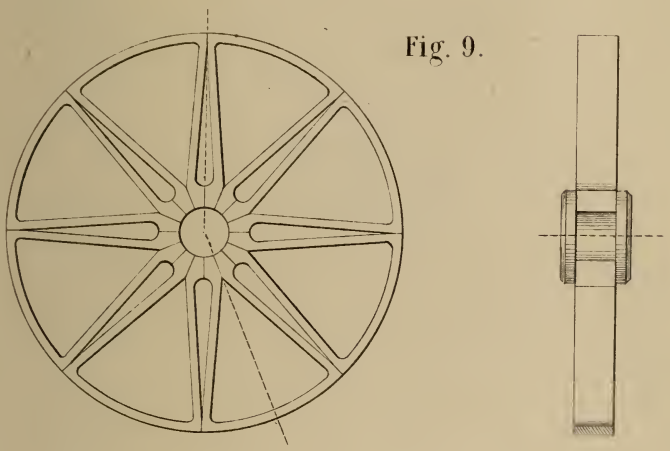
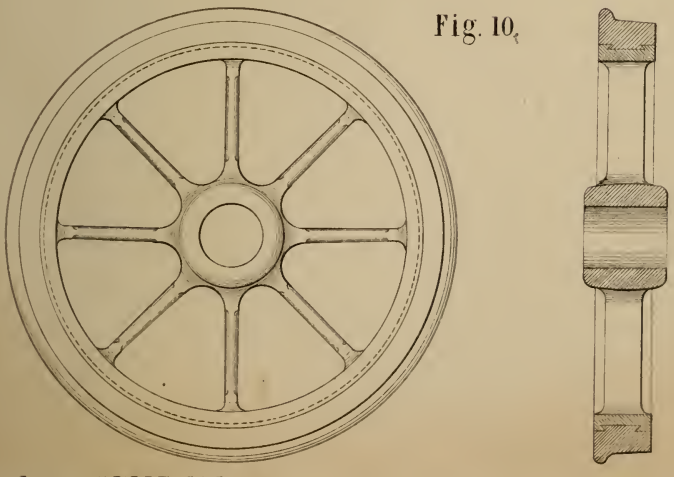


Fig. 10.



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RAILWAY WHEELS.

Fig. 11.
Engine Wheel.

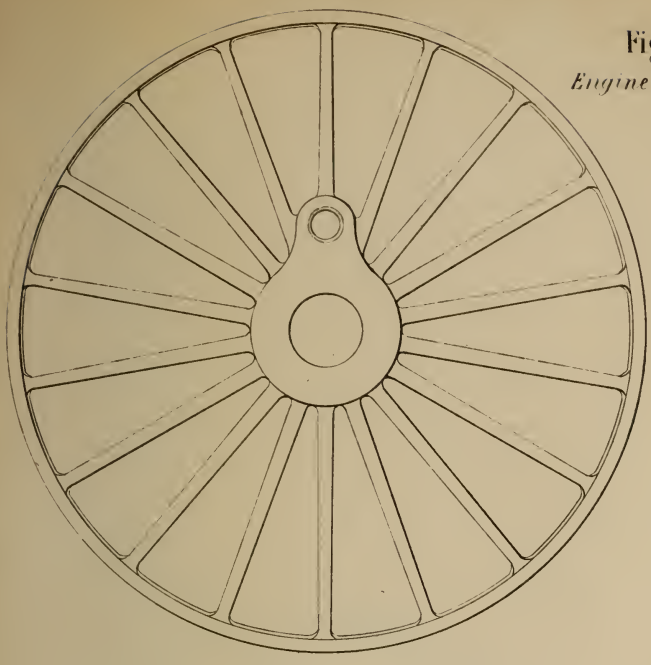


Fig. 12.

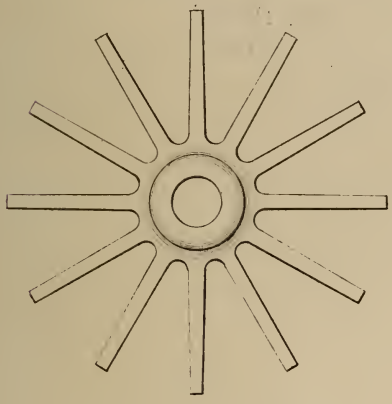
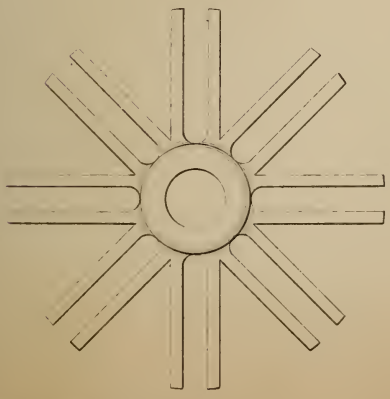


Fig. 12A.



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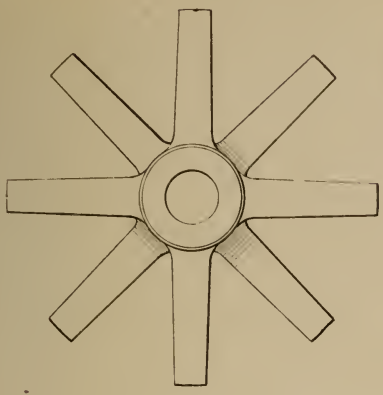

Fig. 12B.

Fig. 13.

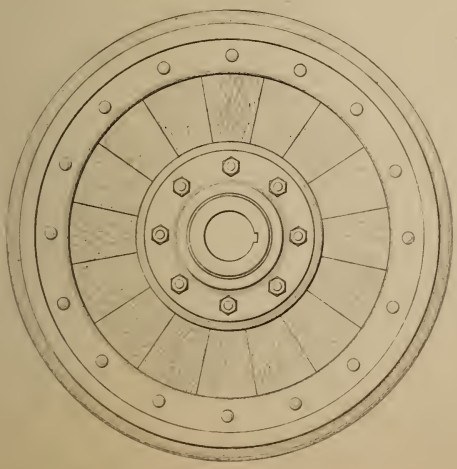

Fig. 14.

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Fig. 15.

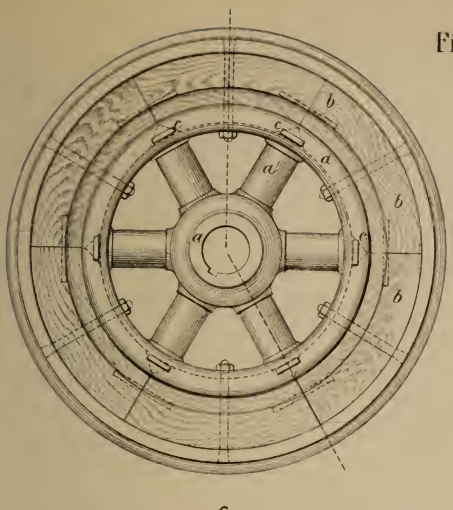

Fig. 15A.

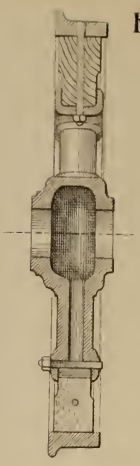

Fig. 16.

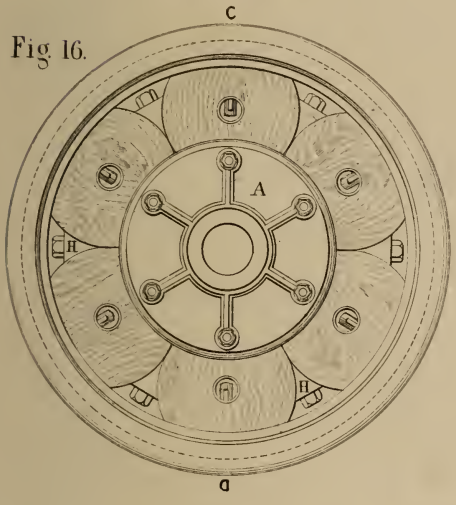

Fig. 17.

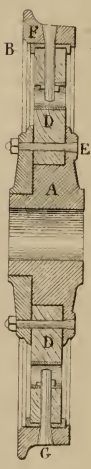

Fig. 18.

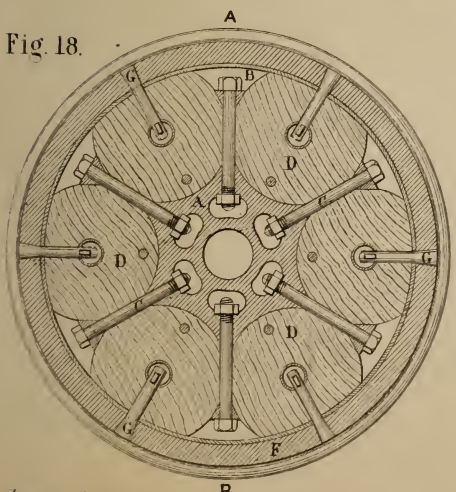

Fig. 19.

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Fig. 20.

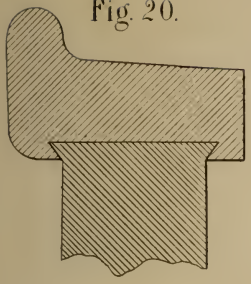


Fig. 21.

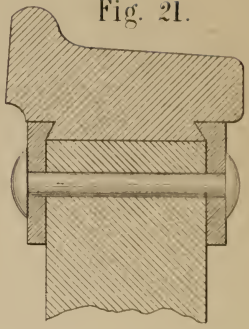


Fig. 22.

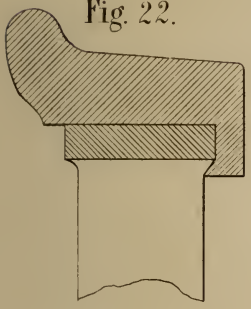


Fig. 23.

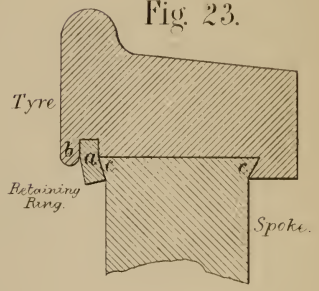


Fig. 24.

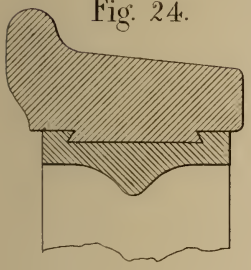


Fig. 25.

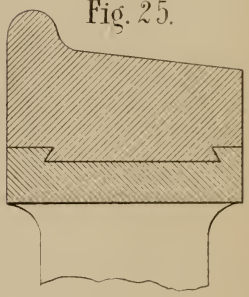
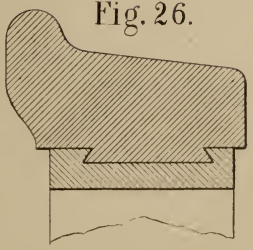


Fig. 26.



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ON THE IRONSTONE OF WILTS AND SOMERSET.

By Mr. G C. GREENWELL, F.G.S.

It is with considerable diffidence that I present this paper to the notice of the Institute, as I am conscious it must contain many inaccuracies: some arising from insufficient information, and others from the districts, together with their productions, not having as yet been fully examined. I will, however, endeavour to keep as free from error as I can, and will at any rate hope that such as I may fall into, will not be on any important points.

We cannot fail to be powerfully struck by the wonderful relation which contrivances and discoveries bear towards artificial and natural wants:—the spinning jenny, the locomotive, and the electric telegraph, with other inventions, almost innumerable, spring into existence just at the time when they could not much longer be dispensed with. But if the resources of mind, as necessitated by human wants are great, the bounties of nature, for similar purposes, are great also.—Our coal fields, in one district, shew symptoms of exhaustion, others are found capable of continuing and immensely extending the supply: a change of law renders it necessary that land should be more highly cultivated, and some powerful stimulant is required,—it is at once discovered: gold becomes scarce, it is immediately found in quantity capable of meeting the deficiency.

The enormous consumption of ironstone in England, is no longer capable of being supplied from its time-established resourse—the claybands of the coal measures,—when the greensand, coral rag, oolite, lias, and red sandstone are discovered to possess it in large quantity, and of almost, if not quite every variety,—from the poorest clayband to the richest hæmatite, and the existence of most of these in Wilts and Somerset, it is the object of this paper to describe.

The ironstone of these counties is peculiar to no geological formation, but is found of different variety in almost every formation from chalk to granite.

1.—In the Lower Greensand we have the deposit discovered and worked at Seend, in Wiltshire.

2.—In the Coral Rag we have that of Westbury, in the same county.

3.—In the Red Conglomerate, a member of the new red sandstone, we have the hydrated peroxide of Clifton, Ashton, Barrow, &c., in Somersetshire.

4.—In the Coal Measures, claybands and blackbands in the lower beds, as in the neighbourhood of Bristol.

5.—In the Mountain Limestone we have occasional fissures filled with hæmatite.

6.—In the Clayslates we have the hydrated peroxides, hæmatites, and carbonates of the Brendon Hills and Exmoor.

I shall, without further preface, endeavour to describe the localities and characters of the ironstones of Wilts and Somerset, but more especially the former, in the above order.

1.—*Lower Greensand Ironstone.*—From the pieces of slag which are frequently found in the fields of the ironstone deposits of Wiltshire, it appears that the manufacture of iron in this county is no new feature: but that in former ages, iron was manufactured there at the same or at an earlier time, and in the same manner, as in

Sussex, and discontinued from the same cause, namely—the exhaustion of the timber required in the manufacture ; and here we have an example, corroborative of the position taken before: no sooner is the timber exhausted than smelting with coal is discovered. Some idea of the extent of this manufacture in Sussex, is given in the following extract from a little book entitled "Mines and Mining.'

"One of the earliest notices of the manufacture of iron in "Sussex, dates in the year 1290, and relates a payment made for "the iron work of the monument of Henry III. in Westminster "Abbey, to Master Henry, of Lewes. In the time of Edward II., "the Sheriff of Surrey and Sussex had to provide within his dis- "trict, for the expedition against Scotland, three thousand horse- "shoes and twenty-nine thousand nails, which with the expense of "carriage and delivery cost £14 13s. 10d. The first iron cannons "cast in England, were made at Buxted, in 1543, during the reign of "Henry VIII, the production of heavy ordinance giving a great im- "pulse to the trade. Richard Woodman, a native of this place and "a considerable iron master, was one of the Marian martyrs, burned "at Lewes, in 1557. In consequence of the great extent of the "manufacture and the enormous destruction of timber, a scarcity "of wood for shipbuilding was apprehended, so that the legislature "interfered in the time of Elizabeth, prohibiting new iron works "except within certain limits, and placing restrictions upon the "consumption of the forests: but in the seventeenth century there "were one hundred and forty furnaces in Sussex alone. Their "multiplication was effectually checked and the existing works "abandoned, when the cheaper method of smelting with pit coal "was discovered. Gradually the noise of the hammer ceased; the "smoke ascended in fewer columns; furnace after furnace died "out; pastoral life regained its ancient ascendancy; and the iron "manufacture vanished from the weald. Yet monuments of it re- "main in some fine sheets of water, though many have, by draining, "been converted into osier beds; and, in St. Paul's Churchyard "the passenger may see a specimen of Sussex made iron in the "balustrades round the Cathedral."

The Lower Greensand Ironstone is found in great perfection in the parish of Seend, where it caps the hill upon which the village is situated. The following is a section,—

	Ft.	*In.*	*Ft.*	*In*
Soil	...	...	3	0
Iron Ore compact	12	0		
Ditto in beds of variable thickness, interstratified with thin layers of sand	13	6	25	6
Blue Clay				

The thickness, however, is very variable: on the summit of the hill its thickness is probably from 30 to 40 feet; but where proved of great thickness, it is interstratified with more sand.

The Greensand Ironstone is traceable over a large tract of country; the following points may be named,—Poulshot, Rowde, Spy Park, and Bowood, and also eastward to Old Swindon; but it only appears to exist in any quantity, where it occurs as the cap of a hill, as at Seend, Spy Park, Bowood, &c. On the lower grounds, the upper or more valuable part of the deposit has been denuded, and it is only traceable by a thin siliceous deposit often found at the surface, with successions of thick beds of yellow sand, in which are interstratified, at various distances, thin beds of argillaceous ironstone, of 1, 2, or 3 inches in thickness. The cap of the hill at Foxhanger, appears to be the base of the principal ironstone deposit; it is there about 6 feet thick, of a soft crumbly character, and of no commercial value. Where found in the neighbourhood of Spy Park and at Bowood, its character is very siliceous: it has here been used for all ordinary purposes, such as road making, and as common building stone. Many of the beds here which apparently consist of blocks of ore, are, in fact, only composed of a casing of hydrated peroxide of iron, the interior consisting of sharp yellow sand: others of the beds consist of small rounded quartz pebbles, agglutinated together by a ferruginous cement.

The following is an analysis of a sample of the Seend ironstone, by Mr. Mitchell, of London:—

	Per cent.
Peroxide of iron	57.150
Protoxide ditto	1·800
Oxide of Manganese	0.315
Alumina	1.072
Lime	0.314
Magnesia	0.721
Potash	0.512
Soda	0.384
Phosphoric acid	0.210
Sulphuric acid	Traces
Silica	26.830
Water	10.412
Loss	0.268
	100.000
Metallic Iron	41.55

The existence of this ironstone has given rise to considerable works, at Seend, whence large quantities of ore have been sent to Wales and Staffordshire. There are also in process of erection, two Smelting Furnaces, which are expected shortly to be in blast.

2.—The next Ironstone deposit to which I shall refer is that of the *Coral Rag.*

I cannot find that the ironstone of the Coral Rag, as discovered near Westbury, in Wilts, has attracted any attention in a commercial point of view, until within the last three years, when it was accidentally found by the writer of this paper. The specimen first observed and analysed, was of a dark green colour, abounding with oyster shells, compact and moderately hard; and, where acted on by the weather, presenting an incipient oolitic structure and slightly ochry appearance.

Further towards the outcrop, and where only covered by two or three feet of the surface soil, the ore is generally in the state of

a hydrated peroxide for its full thickness, its structure being purely oolitic. This ironstone bed dips to the east beneath the Kimmeridge Clay, which will be difficult to work under, after its thickness has become too great to allow of its being bared and thrown back into the quarry whence the ironstone has been removed. The dip is variable, but may be taken at an average of 5°. Rising westward from beneath the ironstone, are the lower beds of the Coral Rag, which, so far as proved, by the following section of a well sunk at the iron works, consist of an oolitic limestone, and, afterwards, a series of sands and marls of the greenish grey colour.

	Ft.	*In.*	*Ft.*	*In.*
Soil	...	...	2	6
Ironstone				
Hard shelly ore	0	9	...	...
Soft ore	0	3	...	...
Compact ore	8	0	...	...
Softer ore with oyster shells	3	0	...	...
			12	0
Greenish blue sand, with oysters, belemnites, ammonites, &c.	...	...	4	0
Light brown sand	...	...	2	0
Blue pisolitic limestone, with beds of marl and sand, not particularly recorded	...	...	52	8
Blue rock	...	...	1	0
Blue quicksand, with a little water	...	...	1	0
Hard blue rock	...	...	1	0
" shelly	...	...	1	0
Blue sand	...	...	1	6
Hard blue rock	...	...	1	6
Loamy blue sand, with large hard concretion	...	...	14	6
Blue marl	...	...	8	10
Rock	...	...	0	9
Sand	...	...	0	9
Into blue rock, with water (20 gallons per minute)	...	...	0	6
Total Depth	...	...	105	6

The action of the weather has produced the effect of altering the colour of the limestone from blue, where it exists under cover of the upper strata, to a yellowish white, where it is found cropping out at the surface, at a short distance west of the above. The gradual transition is well shewn in a quarry by the side of the railway, about half a mile north of the works, where we have, next to the surface, the light brown sand, and beneath it the yellow limestone; gradually changing to the bottom of the quarry, into the blue limestone above referred to. A short distance west of the outcrop of the upper limestone beds, the strata assume a rapid westward dip, by which the ironstone is again thrown in; but about 20 or 30 yards further west, a pit was sunk 20 feet in Oxford clay, shewing the existence of a large upcast fault to the west, in fact the same fault shewn on the Ordnance Geological Map. The throw of this fault cannot be less than 100 feet. The Coral Rag Ironstone is traceable a short distance south of Westbury Railway Station, until it becomes covered by a thick deposit of Kimmeridge Clay, from beneath which it again emerges, and crops out near the first bridge crossing the railway from Westbury to Frome. On the north-east it is found to extend to Steeple-Ashton and the neighbourhood. It is apparently of similar quality to that found at Westbury, but is, so far as I have seen, much thinner and somewhat uncertain in position.

The Revd. W. D. Conybeare, in describing the Coral Rag, (Geology of England and Wales, p. 187) remarks as follows:— "Iron is more or less abundant throughout the sand; sometimes "so much so as to give it the appearance of the ironsand described "in the former chapter."

The following is an analysis of the light coloured limestone by Mr. Mitchell:

	Per Cent.
Lime	45.842
Carbonic Acid	45.991
Magnesia	0.796
Oxide of Iron	0.885
Ditto Manganese	0.721
Alumina	1.102
Potash	0.584
Soda	0.610
Sulphuric Acid	0.897
Phosphoric Acid	Trace
Silica	1.204
Water and Loss	1.368
	100.000

This limestone has been partially used for smelting the ore, but does not suit so well as chalk or mountain limestone. The green stone to which my attention was first attracted, was analysed by Dr. Richardson, of Newcastle-upon-Tyne, and found by him to be composed of—

	Per Cent.
Protoxide of Iron	44.53
Lime	3.37
Magnesia	Trace
Alumina	1.40
Silica	16.55
Loss by Heat	29.77
	95.62
Metallic Iron	34.5

Dr. Richardson adds "The difference is owing to oxygen, part of "the iron being present as peroxide. The iron as metal amounts "to about 34½ per cent. The stone is, in fact, an excellent clay "ironstone and would make good pig iron."

The following are the results of assays and analyses of the brown or crop ore:—

The mean of two assays made by Dr. Percy, of the Government School of Mines, at London, gave 37.8 per cent., and an assay made under the direction of one of the largest Ironmasters in South Wales, aud kindly communicated by him to me, gave 35 to 35½ per cent. of metallic iron:—

	Dr. Richardson.			Walton
	P. C.	P. C.	P. C.	P. C.
Protoxide of Iron	55.80	49 26	...	...
Peroxide of Iron	...	...	...	65.00
Lime	4.94	Traces	1.12	...
Magnesia	2.87	...	...	...
Oxide of Magnanese	Trace	...	...	...
Clay	5.50	...	20 10	...
Alumina	...	14.24	...	4.90
Silica	...	17.10	...	14.00
Phosphorus	0.35	...	...	...
Water	...	...	...	15.90
Sulphur	...	...	...	vy. slt Trace
Loss by Heat	28.00	17,50	27.00	...
	97 46	98 10		99.80
Metallic Iron	43.40	38.31	36.04	45.50

At Westbury, near to the Railway Station, two furnaces have been erected, one of which is in blast, the other in consequence of a failure requiring reconstruction, which is now in progress.—The present production is about 120 tons of foundry iron per week, the ore being used in its raw state. The produce of 3987 tons 10 cwt. of mine, weighed accurately into the furnace, was 1375 tons 10 cwt. of pigs, shewing an actual practical yield of 34.48 per cent. out of the furnace.

The following table exhibits the results obtained by loading various bars of this metal, and will probably be of interest to the

Institute.—They were conducted by myself with much care. The deflections were measured by a little instrument admitting of great accuracy, as will be seen by the following description.

It is 10 inches in length and 1 inch in breadth at one end, tapering to a point at the other; it is divided equally into ten parts, and each part subdivided into tenths. It is applied by being inserted between the deflected bar and a straight edge touching its upper side at its points of support: the length of instrument which can be inserted can then be easily read off; each inch, of course, representing .1 of an inch of deflection, and each tenth representing .01 of an inch. Then as it is easy to subdivide by the eye, the tenths themselves, it will be seen that this gauge admits of a minuteness of examination, approaching to even the .001 of an inch of deflection.

The bars experimented upon were 4 feet 6 inches long between the supports, resting on hard wood: they were one inch in breadth and two inches in depth. The trials were made at Messrs. Cockey and Sons Foundry, at Frome.

It will be observed how closely the deflections of the two bars of the same composition agree, until the load reaches 1456lbs., being in the first case .03474 inch for every 100lbs., and in the second .03445 inch for every 100lbs: for greater loads, however, the effect produced upon the first bar is greater than that produced upon the second, being in the first case between 1465 and 1780lbs .0511 inch, and in the second, .0356 inch for every 100lbs. With a load of 1456lbs. upon each bar, the difference in the deflections only amounts to .004 inch, whereas with a load of 1780 lbs. the difference was .05.—As both bars broke with a weight of 1798lbs., these variations are somewhat remarkable. The followiug experiments were made at the Wick Iron Works, near Bristol, in order to test the amount of waste, in conversion of this iron into puddled bars, from the state of pig metal. The description of iron used was No. 4.—

Weighed into Furnace.			Puddled Bars.		
Cwt.	*qrs.*	*lbs.*	*Cwt.*	*qrs.*	*lbs.*
4	2	4	4	1	20
4	2	2	4	1	25
4	2	0	4	1	21
4	2	4	4	1	27
18	0	10	17	3	9

Equal 20cwt. 1qr. 5lbs. of No. 4 pig make 20cwt. of puddled bars. It was further reported "The above puddled very well; it required "1 hour and 45 minutes on the average from charging, until the "iron was out of the furnace. The furnace was fettled with scrap "cinder, and the iron rather takes up the furnace bottom, which "partly accounts for the extraordinary light waste. The iron

"shingles very well under the hammer, not shewing the least "symptoms of red short; it also rolls very soft in the puddling "rolls and in the sheet rolls."

3.—The next iron ore in succession is the hydrated peroxide and hæmatite of the *New Red Sandstone*, or, more properly speaking, *New Red Conglomerate*, which is commonly found where the conglomerate lies upon or against the mountain limestone. It is found in several localities in Somersetshire, and has been worked at Long Ashton, near Bristol, also at Cleeve, near Yatton. It is also found at Clifton, on Brandon Hill. This ore is very variable in quality: it lies both in veins and beds, and in considerable quantity; but the expense of working it and its general quality, have not as yet caused it to be much used. Its constituents, according to the subjoined analyses, are as follows:—

	Mitchell.		Herapath.
	Per cent.	*Per cent.*	*Per cent.*
Peroxide of Iron	55.027	85.000	81.390
Protoxide of Iron	0.921	...	...
Oxide of Manganese	0.584	1.601	Trace
Alumina	0.352	6.250	...
Lime	Trace	1.087	0.500
Magnesia	0.912	1.458	...
Sulphur	"	0.210	...
Sulphuric Acid	0.110	...	...
Phosphoric Acid	0.372	0.457	...
Silica	40.511	3.304	14.110
Potash, Soda and loss	1.211	0.633	4.000
	100.000	100.000	100.000
Metallic Iron	44.754	58.900	57.000

I am iuformed that iron furnaces are in course of erection at Ashton Vale, near Bristol, at which, as the cost of carriage will be trifling, the Long Ashton, &c. ores may be used with advantage, provided their per centage of silica does not prove injurious; and

the ore can be delivered at the furnaces as cheaply as other ores of the district. As a hematite, however, the general application of which is with the intention of its acting as a corrective to siliceous ores, it cannot be pronounced to be of any great utility. There are several other parts of the county where this description of ore exists, having been discovered in small quantities near the Mendip Hills in various places; the expense of carriage, however, has hitherto prevented it from being much explored. I rather think the ore formerly worked at Wooton Courtney, although probably much more closely allied to the true hæmatite, as found in Lancashire and Cumberland, belongs to this class.

4.—We next will notice, although somewhat cursorily, the ironstone of the *Coal Measures*. Circumstances have not, as yet, been such as to occasion the ironstone of the Coal Measures of Somersetshire to be sought after. The upper series of coal seams, which are those chiefly worked for house use, are found in measures containing very little ironstone, that little being found in nodules sparsely distributed, and in thin bands, rarely two inches in thickness. In the lower series, containing smith's and manufacturing coal, where worked in the neighbourhood of Bristol and near the outcrop of the lower coal strata, towards the Mendip Hills near Coleford, clayband ironstone becomes more abundant, and may be said to be commercially valuable. There are also some beds of excellent blackband to which attention is now being directed, and it may reasonably be expected, that within the next few years, these clay and blackbands, together with the greensand and coral rag ironstones of Wilts and the pure coals of the lower series of Somerset, ought, in the ordinary course of events, to lay the foundation of a great iron manufacture in these counties.

5.—The iron ores of the *Clayslates* have recently been opened out, and are now being worked on the Quantock Hills and on Exmoor, in Somersetshire. Of these I am only able to give a very slight notice, and I regret this the less, as I have no doubt they will form the subject of a paper from our late President, who has bestowed so much pains upon their developement. These ores

appear to lie in veins in much the same manner as metallic lodes of any other description, and consist of carbonates and oxides of great purity. They are not, however, as yet very extensively worked.

Some years must of course elapse before there can be in operation in Somerset or Wilts, such splendid monuments of skill and perseverance as we find exhibited in the gigantic iron works of South Wales; but still, it must not be forgotten, that even the giant was an infant once.

Only eight years have elapsed since the discovery (practically applied) of the ironstone of Cleveland. In 1837, the report of the Tyne Iron Company, on a sample sent them for trial was that "they were ashamed to see such refuse on the quay;" and it was not (although it was long known), until the end of the year 1850, that it was fairly brought into use.—(Marley. Trans. N. E. Inst. of Mining Engineers, vol. 5, p. 188.) Since this period, however, and entirely owing to the Cleveland stone, no fewer than 64 furnaces have been erected, nearly the whole of which are in blast. Previous to this the total number of furnaces in the North of England, eight of which were out of blast, was only 37. The quantity of ironstone produced from the Cleveland mines, exceeds 1,500,000 tons per annum, yielding 500,000 tons of cast iron. In 1857, the make was

	TONS.
From Cleveland Ironstone	500,000
South Wales (*Hunt's Statistics*)	970,727
Scotland *ditto*	918,000
North and South Staffordshire & Worcestershire *ditto*	791,352

The total British produce of pig iron in 1857, was according to the same authority, 3,659,447 tons to which the Cleveland ironstone contributed nearly one seventh; and this after a commercial existance of only seven years: and now several new furnaces are in course of erection.

It is not, of course, easy to foresee what will be the result of the discoveries of iron ore in Wilts and Somerset, more especially, however, of the former. Many circumstances will affect this.—

The rapid developement of the parallel discovery of Cleveland, is to be found to a great extent due to its excellent situation, both for export to the Continent, and for supplying the large local demand of a great iron consuming district; to the facilities given and cheap transit afforded by the railways, now reaping golden results from their wise foresight; and, though last not least, to the enterprising spirit and ample means, which are now in a fair way to make the North of England iron trade of rival magnitude with its coal trade —the largest in the world.

And why should not similar results be obtained here? The quality of the ironstone of Wilts is, to say the least, as good as that of Cleveland. Any site where furnaces exist or might be erected will, so far as the first cost of ironstone on the works, and ought to be, so far as the cost of transit, are concerned, supplied as cheaply as any site of equal distance from the mines in the North of England; and the same scale being applied to fuel,—why should not similar results be obtained here to those that we see there?—No doubt the old words "similia similibus" are adaptable to Wilts and Somerset, as well as to Northumberland and Durham.

Mr. T. Evans remarked that this paper was a valuable and important one. It was impossible that they could follow its reading so as to be able to discuss it at their present meeting. He would therefore throw out the suggestion that it should be postponed until a future day.

Mr. Edward Riley, in referring to the ores alluded to in the paper of Mr. Greenwell, remarked that he had been engaged very largely in the analysis of this description of ore. He had analysed samples containing from 30 to 50 per cent., but the average he found was only 29 per cent., and he thought this a fair average, judging from some thousands of tons he had seen two and three years since.

The Chairman would remind Mr. Riley that it was proposed and seconded that the discussion should be postponed.

Mr. Evans said they had better hear what Mr. Riley had to say, as that gentleman resided in London; they would not perhaps have the advantage of his presence at the next meeting.

Mr. Riley continued to observe that the physical character of iron ores was of much importance. The Welsh ironstone, although compact, by calcination became to some extent porous, and was readily permeated by the gases of the blast furnace. This was also the case with the Northampton ore, and some other porous ores; the consequence was they were the more easily smelted. The Llantrisaint ore, on the other hand, was much more compact, and not only this, it was interstratified with layers of quartz. The gases of the furnace did not penetrate the ore, and the consequence was its reduction at a higher temperature; the silica being reduced, and passing into the iron in the state of silicium. This was found to be the case with the Wiltshire ore, which appeared to be a conglomerate cemented together with hydrated peroxide of iron, the oxide of iron varying in quantity. Sometimes the ore was tolerably free from quartz, but, as a rule, it was very siliceous, and the consequence was a siliceous pig was produced from it. The Wiltshire ore was formed from the carbonate by slow decomposition, in the same way as Northampton ore, and the original stone appeared to contain particles of quartz similar to the decomposed ore. In comparing this ore with the Cleveland ironstone, there was this difference; the Cleveland ore contains a large quantity of carbonic acid, which was volatile and easily got rid of, whereas the Wiltshire ore was siliceous, and this would require coal and stone to flux it, and would at the same time get into the iron and materially deteriorate the quality of the pig, giving it a smooth face with a purple sort of bloom on it; pig of this description was always siliceous, and not only worked to a bad yield, but puddlers frequently would not puddle it at all, the yield being frequently from 25 to 27 cwts. No doubt that by mixing it with other ores and working the furnace heavy on stones this might be to some extent alleviated. With regard to the Long Ashton Ores, they contained a large per centage of Sulphate of Baryta, which, from its great density, was frequently

mistaken for oxide of iron (as it was always more or less colored with it) the density of Sulphate of Baryta being greater than that of hydrated peroxide of iron, and nearly equal to that of the anti-hydrous oxide. Mr. Riley had observed Sulphate of Barium floating on the surface of pigs made from this ore.

Mr. Cox would second the proposition for postponing the discussion upon this interesting paper, at the same time it would be most convenient could the time for discussing it be now decided, otherwise it might be brought on when not anticipated.

Mr. Riley wished it to be understood by the meeting, that his observations referred to what he had seen in Wales, and not in the district mentioned in Mr. Greenwell's paper When he had an opportunity of examining the ores from that district, he might perhaps alter his opinion.

The proposition for adjourning the discussion to the January meeting was then put to the meeting and carried unanimously.

Mr. Menelaus thought that the members should not separate without proposing a vote of thanks to Mr. Greenwell for his very able and interesting paper.

Mr Cox seconded the resolution, which was carried unanimously.

The Secretary read the following paper;—

ON WORKING AND VENTILATING THE STEEP MEASURES OF SOUTH WALES.

By Mr. GEO. ROBSON.

This paper will only treat on the results of my own experience, and will be confined to a district which has, from time to time, come under my own inspection, extending from Trecastle, by Llanharran, Pencoed, Tondu, Cefn, Bryndu, and Port Talbot, embracing the seams of Coal and Ironstone, upwards from the Cribwr Vach Coal (the lowest in the basin, with the exception of one or two very thin seams near the Millston Grit), to the Rock Fawr Measures.

The average direction of the dip is north, at an average inclination of 18 inches ℔ yard. It will be seen by reference to the section, what an important coal field is included in the tract of country referred to, containing eight seams, equal, in the aggregate, to a thickness of 50 feet; and all of which are generally found in a workable condition, producing coal well suited for household purposes, the mannfacture of coke and iron, and also for steam purposes.

The Ironstone seams are also numerous and of average quality, and moderately cheap to produce. Faults are not very numerous. Railway communications with shipping ports are on the increase.

Combining all these facts, it is only reasonable to conclude that the district I allude to, will, in a short time, take a very important standing in the coal trade of South Wales; and as the winnings will be deep, the coal and iron seams reposing at such a great inclination, with many other pecularities not found in other districts, the developement and working of these measures will require great skill, to contend with the several difficulties that will be met with; and I therefore submit the following observations to your notice, with a view of drawing the attention of practical men to this interesting subject.

There can be very little doubt that the proper way to win any portion of this mineral field, will be to sink to the deep of the coal field to be won "coffering" the water back met with. in sinking, and the probabilities are, (judging from what I have seen in collieries in the neighbourhood) little or no water will be found in the coal seams: and the coal will then be to the rise of the shaft. But in the case of a pit 600 yards deep, equal to 1200 yards of range, I apprehend that inclining the coal down so steep and so long a declivity, will render it difficult to keep the inclines and other necessary openings in repair for a long period of time, and materially increase the working costs of the colliery. Probably the pit sunk in such a position as to leave 300 yards of coal to the deep, to be worked in conjunction with 300 yards to the rise, may be the most economic method: a pit of 450 yards in depth then will suffice, and when the 300 yards to the rise is exhausted, I am of opinon, that a new intersection of the seams might be advantageously made ,at a point say 160 yards higher up the shaft: thus lessening the length of inclines, &c., and the depth of the shaft.

The workings to the deep will form an immense lodge room, and, by working the pillars there first, I have found that headings to the rise stand better and are less liable to crush, owing, I should say, to the pressure coming from the deep. In case of a fall to the surface I have always found that the fracture of the strata extends at right angles to the dip. (See diagram 1.)

Commencing operations at the "crop" cannot be too much condemned, and an incalculable amount of iujnry and loss is, and has been sustained by both landlord and tenant from this reason. There is, as many of you are aware, great difference in the character, hardness, quality, thickness, and nature of the tops and bottoms of the South crop seams, and these circumstances effect the mode of working and ventilation to a very great degree. Perhaps the best, and eventually the cheapest way, is to drive the headings out to some boundary before commencing the operation of pillar working, but this is not always convenient or practicable.

I will begin first by describing the mode of working the soft coals, having bad tops and bottoms. Diagram No. 2 represents the general plan adopted.

The pillar between the heading and the windroad is only about 12 yards, and the stalls and topholes are driven 10 yards apart, and holed at intervals of 10 yards, to the extent of from 60 to 80 yards from the heading. They are necessarily, owing to the roof, driven narrow and timbered, so also are the holings between each tophole. The pillars thus formed are very small, consequently weak and liable to be crushed by the superincumbent strata, aud the elastic force of the bottoms. Each holing must also be furnished with a stopping to carry on the ventilation to the face.

I will suppose that "working" the pillars has commenced at the top; the first range may be got out without much crush, (but not all the coals by any means) but the operation of extracting these to the deep, as the pressure comes from the north, is much more difficult, and the topholes and holings between them require reopening and retimbering frequently, at a very great expense.

The loss of coal by this method is detrimental to both the interests of the lessor and lessee. To avoid these evils I have adopted, and successfully carried out (see diagram No. 3), a system of 20 yard pillars, which are extracted when three stalls are driven up 80 yards, and after the formation of a gas drift on the top; the pillars are split in the middle, and two men working to the right and left of every tophole; (thus 12 men are employed,)

exhaust the coal to within 20 yards of the windroad, or within 40 yards of the heading, with great dispatch.—The advantages in this method consist in a saving of timber and labour, arising from the workings being kept stronger; and double the quantity of coal is got for little more timber than is used by the method shewn in diagram No. 2.

A few holings made into the gas drift entirely prevents any accumulation of gas. A separate split is made at crossing marked B, for ventilating the Pillar District, thus lessening the friction and danger of cutting off the supply of air in the workings in advance, as occasionally the airways in the Pillar District will become very small, and falls occur, which sometimes close the "Return." Two or more of these districts might be worked at one time, provided care be taken in working them out at a proper angle.

Owing to the ever changing size of the Topholes it would not be practicable to use a self-acting incline for bringing the coals down, and the cheapest way is to barrow them from the working places into the Topholes, which, when planked at the bottom, keeps the coal clean, and assists its descent. Great despatch ought to be used in driving up the Stalls, and two turns of men ought to be employed in bringing back the Pillars.

No. 4 Diagram is intended to show the system pursued in the hard coal, with good tops. Here, as in diagram No. 3, small Pillars are left between each stall, which are five yards wide, and, when driven the required distance to the rise, the coal is brought back The coal descends the stalls by its own gravity, and is laden into trams at the bottom of each stall. but it is very much fractured in its descent, and generally crushed some little in the pillar. Every stall is to be bratticed from the Windroad to the face, and the current is only kept in its course by canvass doors, through which the coal must pass to be laden into the trams.

To avoid these drawbacks by such a system of working, level course stalls have been sometimes employed, and the trams taken into the face of the working places, filled aud inclined into the

Heading, but, owing to the difficulty of stopping the tram at the end of each working place, they have been in a great measure abandoned, as being more expensive, and the improved yield of large coal not compensating for the expense of inclining and tramming; my own experience however shows different results.

No. 5 diagram will show a level course working, which I have found advantageous, both as regards ventilation and extra produce of large and coal. The roof of the seam worked requires props and collars: the stalls are driven out 80 yards right and left of the incline tophole; they are from 4 to 5 yards wide, and 15 yards between them. Occassional holings are made from stall to stall to shorten the bratticing When the stalls have all been driven to the required, the coal between the stalls is extracted by taking 4 yards off the end of the pillar, and repeating this until the pillar is finished. Many of the props can be got out, and a fall cannot materially interfere with the workings; as solid coal is always on the outside of the goaf. The ventilation is conducted as shewn on diagram.

Diagram No. 6 shows another system of working a seam of coal possessing a good top and bottom, and which I have worked previously by stalls, similar to Diagram No. 4. The working can be commenced at any place in the heading. I consider 80 yards from each side of the incline to be a sufficient distance, and the men commence work at the extremities. Four or five men may be employed on each side, one in the opening in the solid coal to the rise, and the other four, at the face, keeping from two to three yards one before the other, and when they advance 15 yards to the rise they stop after securing the face, and return and take another portion of the pillar out to the same height When the coal on both sides is thus worked the incline machinery, of very simple contrivance, is removed, the tramroad relaid at the face, and the same operation is continued up to a distance of from 80 or 100 yards from the heading.

I have departed from the usual custom, by writing on the diagrams looking south instead of north, finding it much more convenient in plans of south crop workings.

To prevent the breakage of coal I find that allowing the small to remain for the large to fall upon is worth doing, but, of course, if any danger is apprehended from the roof, risking the loss of it, the Overman may cause its removal. It is very necessary that as many of the props as possible should be got out to allow the roof to subside, and thus take the pressure off the pillars. The ventilation in this case is very simple, the coal is got very large and very little left, and the expense of narrow work, &c., much reduced. This is nearest approaching to long wall work that I have seen effectually carried out in steep measures. The great difficulty in working long wall work seems to be the want of rubbish or stones to construct Gobwalls with, where such exist the operation seems simple.

The size of Trams I have found best adapted for working Measures in this district are light, but strongly built, and do not carry more than from eight to nine cwt. of coal, they can be applied in windroads, topholes, and stalls, and are easily propelled by a boy. When bottoms of seams are apt to swell, and derange the roads, the liability to trams getting off the rails becomes great, and a large tram requires more than the strength of an ordinary boy to replace it: and again, as two or more seams are generally worked at one pit, and vary in height, it is important that the tram should be of such a size as to work in any of them.

In this district two or more seams are generally intersected by a drift across the measures, and worked to one pit. Headings are excavated in the coal from the right and left of the drift. It is necessary to have an intake and return airway, and failing having any communication with the surface, with the exception of the Downcast and Upcast Pits, recourse must be had to two drifts, or, what is more general, a drift wide enough for an Intake and Return divided by a brick wall, or ventilating by one current, which requires doors, and short walls. A brick partition with an arrangement of crossings provides for the air being split at the end of each heading; the same is the case with two drifts driven parellel to each other on the same level. (See Diagrams No. 7 and 8.)

As I have said before, if the drift is divided by a partition, it must be made of sufficient width for the purpose of an Intake and Return Airway, thus increasing the cost of driving it. The expense of building the partition will be considerable, and, in ground with an elastic bottom, decidedly expensive to keep in repair and air-tight; and the same may be said in reference to the crossings, that it is evident the first expense is very little less.

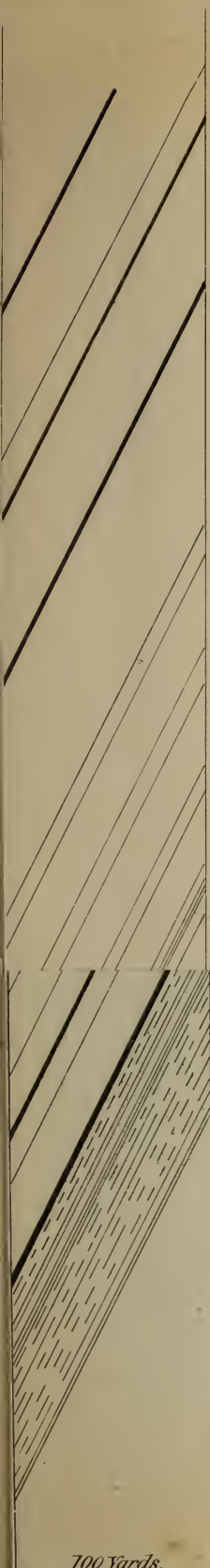
Next, as regards driving the drifts parallel to each other and on the same level crossings; and pits or sloping drifts from the junction of the windroads must be made into the return, adding considerable friction to the air.

No one will dispute but that the judicious subdividing of air in coal mines is highly beneficial in many points of view, and, in one case which came under my own notice, by dividing one current of air into three, a result of four times greater was got and maintained without any increase of ventilating power; therefore, in order to carry out the system of splitting air effectually, I have had recourse to driving one drift above the other, the lower drift being the Intake, and the upper the Return. Ten yards perpendicular between the two drifts will give 20 yards of coal pillar between the heading and windroad, and the windroads thus come level into the top drift. By this plan crossings and doors are entirely superseded, every heading can be ventilated separately and isolated from other headings, and the air regulated as required by means of regulators in the return. In case of explosion no fear need be entertained of crossings or brick walls being blown down, what is required is that the Downcast and Upcast Pits, together with the intake and return airways, are of sufficient size, with proportionate ventilating power. The furnace can be placed as shewn in the large plan, and fresh air admitted from the Downcast Pit for the combustion of the fuel, and. The return air need not pass over the fire at all.

It was my intention in this paper to have referred at some length to underground transit, the relative difference between Ventilating Deep and Rise Workings, and to have made some remarks respecting the position of Upcast Pits, but as time would not permit me I now conclude my observations.

STEEP MEASURES OF SOUTH WALES.

Plate 41.



	Ft.	Fe.	In.	Yds.	Fe.	In.
			MINE	COAL	MEASURES	
Rock Fawr Coal	"	4	"			
Fire Clay						
Bluish Building Rock				77	"	"
Dderllwyn Coal	"	4	"			
Blue Shale				110	"	"
Coal	"	1	8			
Reddish Rock				22	"	"
Coal	"	1	7			
Fire Clay						
Cockshut Stone				44	"	"
Shale						
Coal	"	1	4			
Coarse Tight Sandstone				22	"	"
Cockshut Coal						
Sandstone						
Shale				44	"	"
Small Vein Coal						
Strong Rock				51	1	6
Shale						
Wet and Dry Coal	"	2	6			
Shale						
A Vein and Pin of Ironstone	3	"	"			
Small Vein Coal	"	1	6			
Shale				11	"	"
Coal						
Shale				33	"	"
Bottom Measures of Ironstone	72	"	"	100	"	"
Gribwr Fach Coal	"	2	6			

100 Yards.

Proceedings, S.W.I.E. 1859. Andrew Reid, Lithographer, Newcastle.

STEEP MEASURES OF SOUTH WALES.

Plate 41.

MINE COAL MEASURES

	Ft.	Ft.	In.	Yds.	Ft.	In.
Rock Fawr Coal	"	4	"			
Fire Clay						
Bluish Building Rock				77	"	"
Dderllwyn Coal	"	4	"			
Blue Shale				110	"	"
Coal	"	1	8			
Reddish Rock				22	"	"
Coal	"	1	7			
Fire Clay						
Cockshutt Stone				44	"	"
Shale						
Coal	"	1	4			
Coarse Tight Sandstone				22	"	"
Cockshut Coal						
Sandstone						
Shale				44	"	"
Small Vein Coal						
Strong Rock				51	1	6
Shale						
Wet and Dry Coal	"	2	6			
Shale						
A Vein and Pin of Ironstone	3	"	"			
Small Vein Coal	"	1	6			
Shale				11	"	"
Coal						
Shale				33	"	"
Soap Vein Coal	"	1	6			
Four Courses of Ironstone	7	"	"			
Black Pin Coal				22	"	"
Shale				143	"	"
Three Courses of Ironstone	6	"	"			
Lantern Coal	"	3	"			
Balls	9	"	"			
Shale				44	"	"
Four Courses of Ironstone	8	"	"			
New Vein Coal	"	6	"			
Shale				88	"	"
Three Courses of Ironstone	8	"	"			
Gwythian Each Coal	"	2	"			
Four Courses of Ironstone	12	"	"	22	"	"
Boder Each Coal	"	2	"			
Thirteen Courses of Ironstone	36	"	"	33	"	"
Y. Boder Coal	"	9	"			
Balls of Ironstone	6	"	"			
Vein and Balls 4 ft above Coal	9	"	"			
Escrin Coal	"	4	"	22	"	"
Three Courses & Pin of Ironstone	10	"	"			
Shale				110	"	"
Ground 4 ft with Balls of Ironstone	8	"	"			
Ironstone 4 ft above coal	4	"	"			
Fawr Coal North Wing	"	10	"			
Shale				18	"	"
D° Middle Wing	"	9	"			
Shale				22	"	"
D° South Wing	"	8	"			
Shale				22	"	"
Yr Ail Coal	"	6	"			
Shale				33	"	"
Y. Drydydd Coal	"	5	"			
Shale				34	"	"
Gwythian Each Coal	"	3	"			
Shale				44	"	"
Chwech Troedfedd Coal	"	6	"			
Shale				44	"	"
Slatog Coal	"	4	"			
Shale				36	"	"
Slatog Coal	"	4	"			
Shale				44	"	"
Limog Coal	"	3	"			
Shale				19	"	"
Naw Quater Coal	"	9	"			
Shale				26	"	"
Pimp Quarter Coal	"	5	"			
Shale				44	"	"
Cribwr Fawr Coal	"	4	6			
Bottom Measures of Ironstone	72	"	"	100	"	"
Cribwr Each Coal	"	2	6			

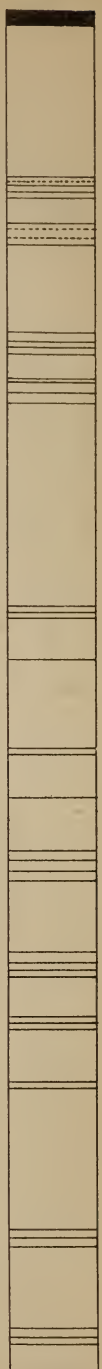
100 Yards.

Andrew Reid, Lithographer, Newcastle.

STEEP MEASURES OF SOUTH WALES.

Plate 42.

	ft	in.
Cribwr Fawr Coal	4	6
Rock and Shale with Nodules of Ironstone	41	"
Spotted Vein Measures in several Pins & Balls	"	5
Shale	3	3
Several Pins & Balls	"	5
Rockey Shale	18	5
Yellow Vein	"	5
3 Pins of Ironstone	"	4½
Shale	3	3
Top Red Vein	"	3½
Red Mine in 3 Courses	"	5½
Blk. Shale		
Blk. Vein Ironstone	"	2
Rock and Shale		
Pin	"	4
D°	"	1
Shale	5	3
Veins of Ironstone	"	4
Shale	21	9
Black Pin	"	2
Dark Shale	6	6
Shale Rock	19	9
Veins of Ironstone overlaid by Pins & Balls		4
Shaley Rock	16	6
Poor line rejected	"	6
Shale	10	6
Vein of Ironstone and Pin	"	5
Shale	6	6
Ironstone	"	4
D° Pin		2½
Hard Shale	14	6
Hard Shale	15	10
Two Courses of Ironstone	"	4½
Black Shale	10	6
Black Shale	15	"
Gwythian Gnapog Pin Garw	"	4
Cribwr Fach Coal	2	6



Total Ironstone Bottom Measures 72 Inches.

Calculated ... 66

Poor ... 6

Andrew Reid, Lithographer, Newcastle.

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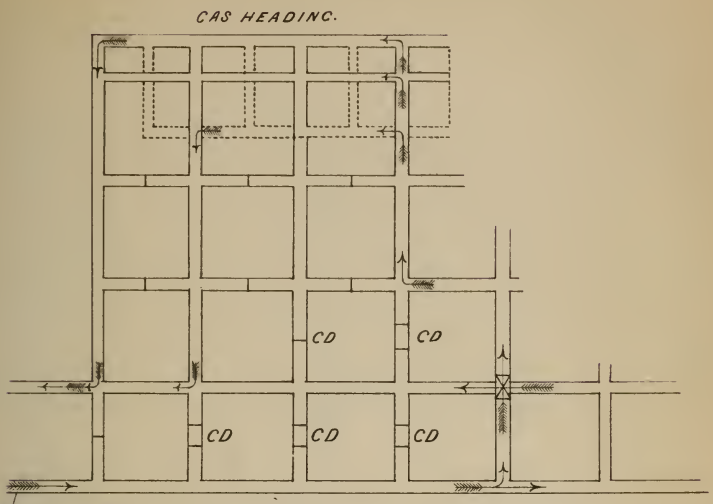
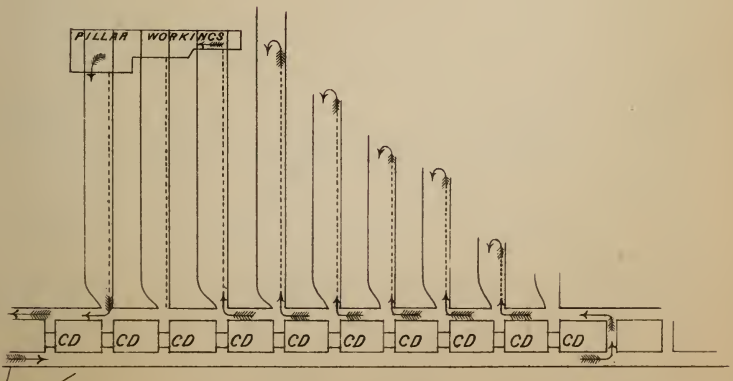
DIAGRAM No. 3.



Scale 20 Yards = ½ Inch.

CD Canvas Door
— Stopping.
⊠ Crossing

DIAGRAM No. 4.



Scale 20 Yards = ½ Inch.

C.D. Canvas Door

Andrew Reid, Lithographer, Newcastle.

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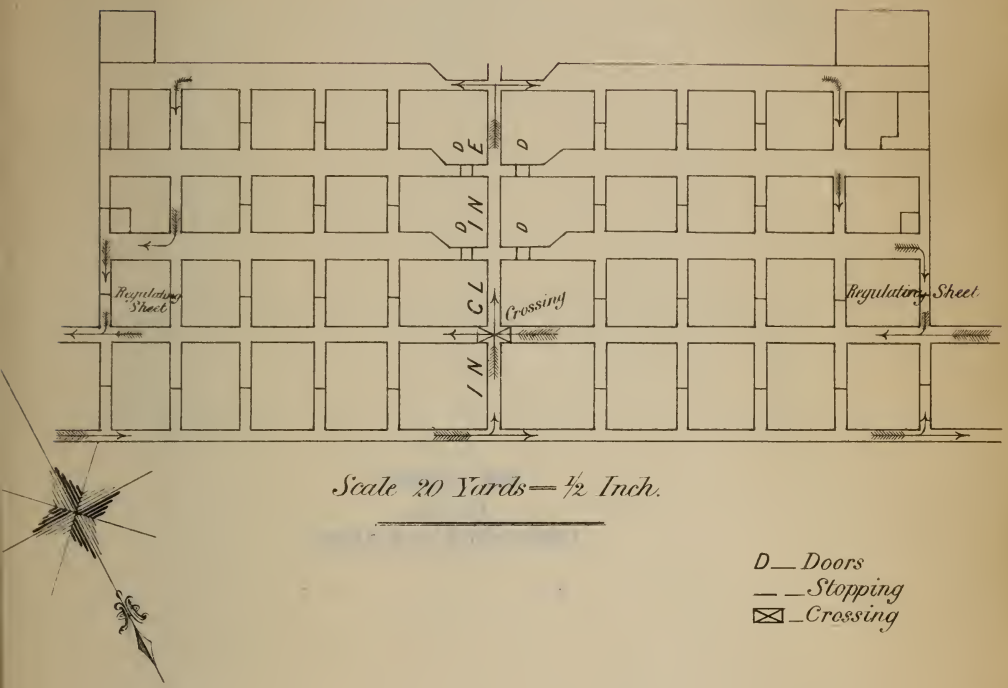
STEEP MEASURES OF SOUTH WALES.

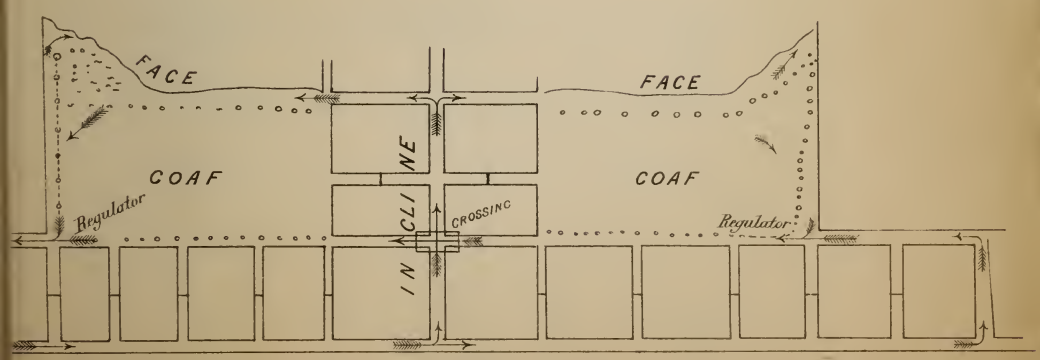
DIAGRAM No. 5. *Plate 45.*



Scale 20 Yards = ½ Inch.

D__Doors
__Stopping
⊠_Crossing

DIAGRAM No. 6.



__ Stopping

Scale 20 Yards = ½ Inch.

Andrew Reid, Lithographer, Newcastle.

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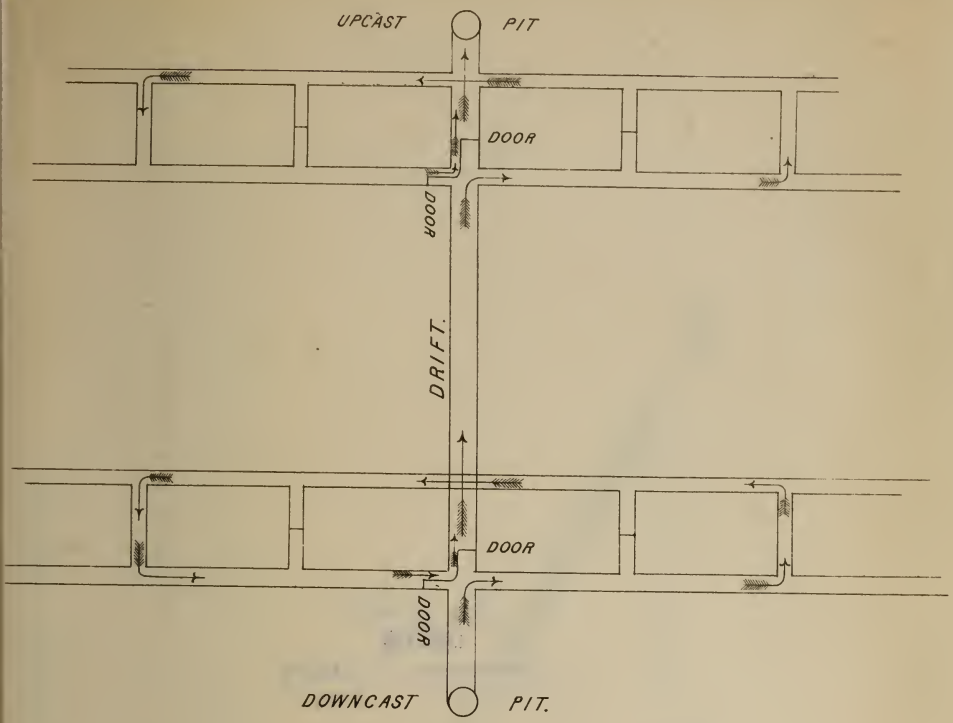
STEEP MEASURES OF SOUTH WALES.

DIACRAM No. 7.

Plate 46.



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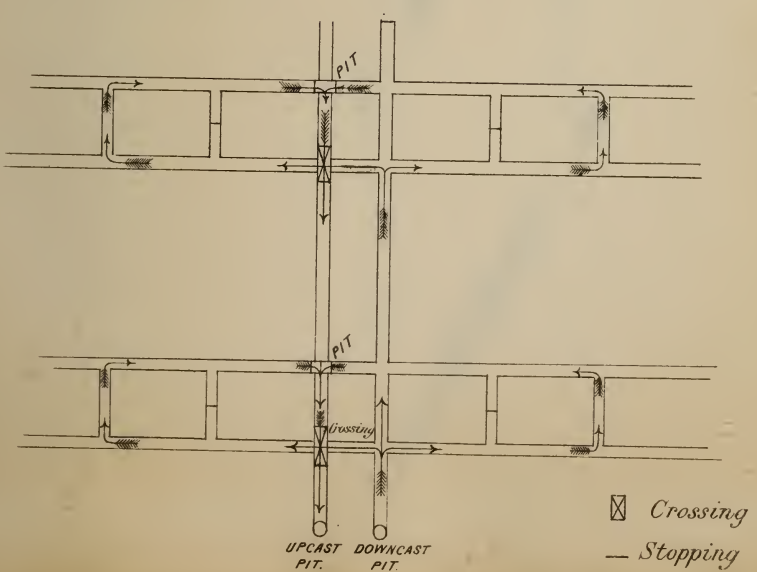

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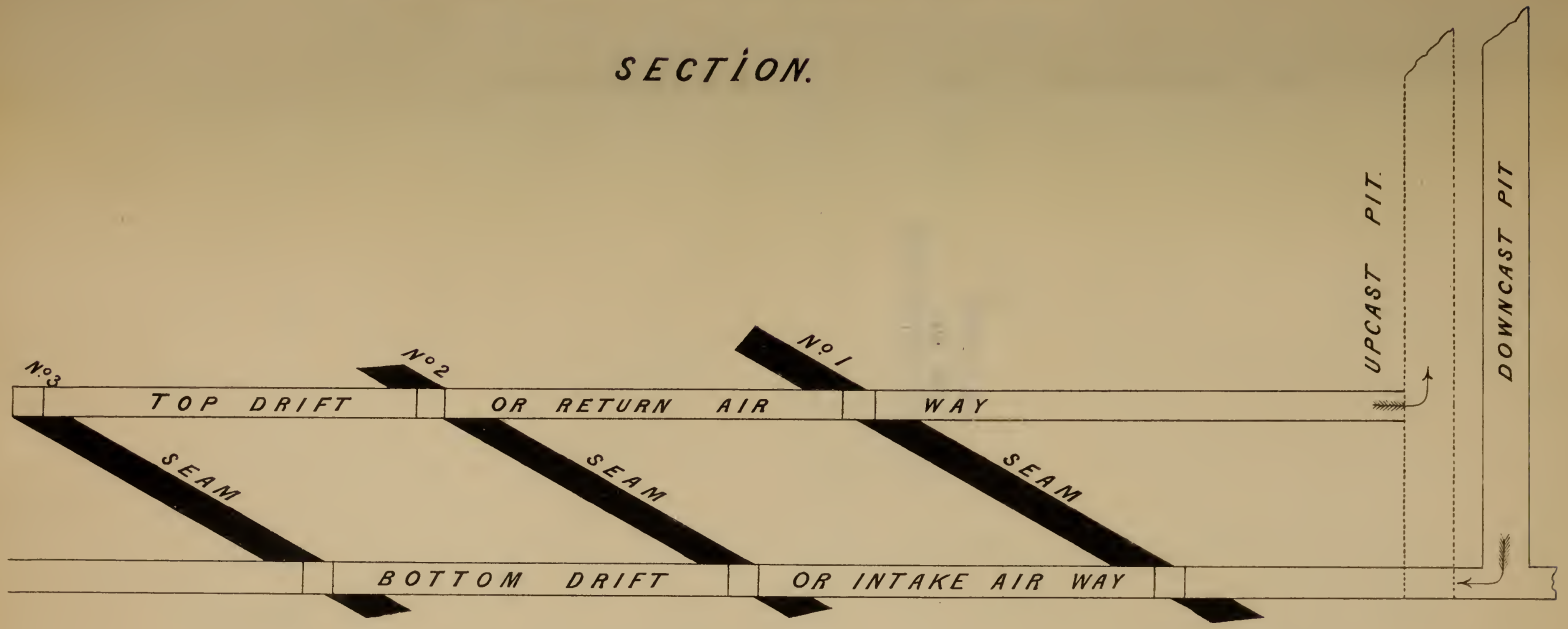
STEEP MEASURES OF SOUTH WALES.

SECTION.



☐ *Represents the Entrance of the Headings and Windroads from and into the Lower and Upper Drifts.*

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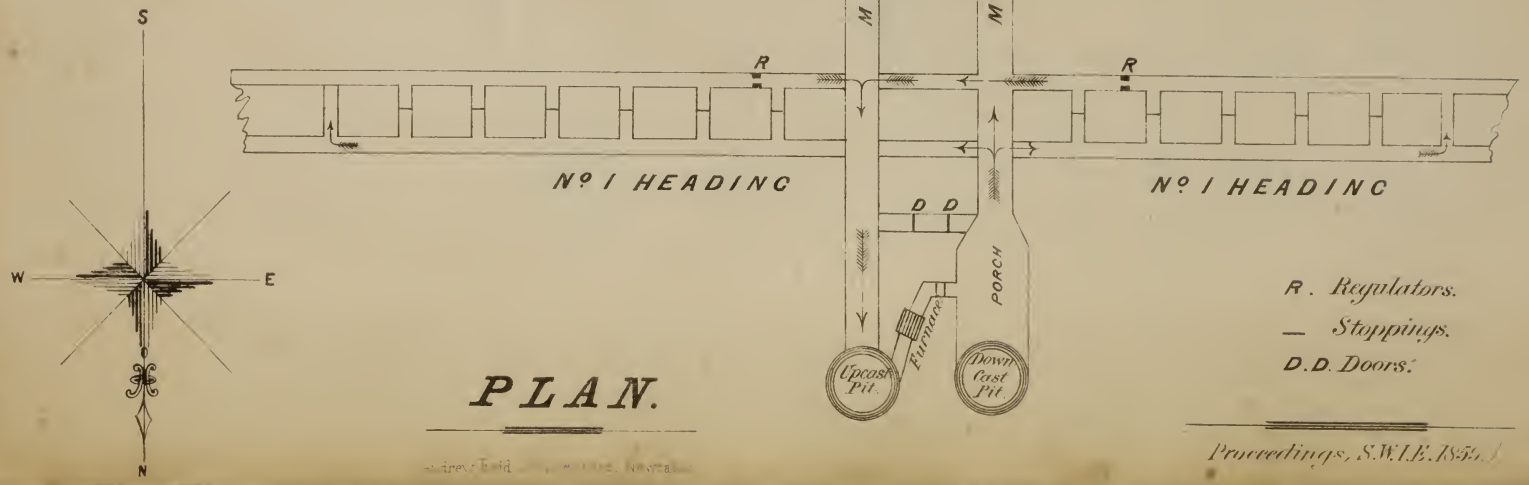

PLAN.

Proceedings, S.W.I.E. 1854.

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Mr. CLARK said this subject was one of particular interest to many of the friends present. He himself could not but feel the deepest interest in a subject which came home so close to many of them. The paper being of such importance its discussion ought to be postponed, and he would therefore move that it be postponed accordingly.

Mr. T. EVANS would be most happy to second Mr. Clark's proposition that the discussion of the paper be adjourned. The paper read by Mr. Robson was of the greatest importance to those in this and of the county,— those living near and around Swansea, where in the middle of steep measures. Being of such importance he hoped they would adjourn the discussion.

Mr. R. BEDLINGTON hoped the paper would be discussed at the next meeting, or perhaps they would not get it on at all.

The CHAIRMAN said it was for the meeting to fix the time for the discussion of the paper. Mr. Clark and Mr. Evans had proposed that it should be adjourned, and if that was carried, then the time for discussing it should be fixed. The matter was of very great importance, more especially to this district.

The resolution for the adjournment of the discussion was then put, and carried unanimously.

Mr. MENELAUS proposed that Mr. Robson's paper be discussed at the next meeting.

This resolution was duly seconded and carried.

The CHAIRMAN said that the next paper was in reference to an important requirement of the present day, viz:—" A Self-Acting Steam Break, for the prevention of accidents by over-winding."

The Secretary then read the following paper;—

ON THE STEAM BREAK AND RECORDING ENGINE, AS APPLICABLE TO COLLIERY WINDING ENGINES, FOR THE PREVENTION OF ACCIDENTS BY OVERWINDING.

By Mr. OGDEN, of Manchester.

One, and by no means the least, of the accidents to which miners are exposed, is overwinding. Many schemes by various persons have been planned, to prevent this class of accidents. I propose now to bring before you, the Self-acting Steam Break and Recording Engine, as applied to colliery engines for the afore-named purpose.

I need not refer you to any historical relations concerning the adoption of breaks to colliery engines, or to the government conditions with reference thereto; nor to the fact, that the days of slow winding with carts seem to be numbered, for the best reason, viz.: that winding quick and with guides is considerably better, and cheaper in the end; and I think you will agree with me when I say that, in proportion as you incease the size of your winding engines, and left more rapidity from the mine, in the same proportion the tendency to accident by overwinding is increased. I believe, and experience hitherto has confirmed it, that with the adoption of the self-acting break, quick winding is rendered equally safe as slow winding, and I venture to offer this reason as my excuse for bring-

ing this matter before you. Therefore I will proceed to the subject of this paper by first shewing the causes of overwinding, and, afterwards, the utility of the Steam Break, as a preventative of such accidents.

First Cause.—*Deficiency of steam and weight of the down rope.*—At single winding engines, and where there is no balance to ease the weight of the down rope from the engine, it requires nice attention on the part of the engineman to safely make the first revolution (especially in deep mines); for should there be any deficiency of steam at the time, and the engine get near its centre, it is well known the engine will be at that point of the revolution most unmanageable, and there is great danger of the weight of the down rope drawing the up cage, or corve, over the head gear, before the engineman can get sufficient control over the engine to bring her up.

Second Cause.—*The Sticking of Valves.*—This cause of overwinding occurs mainly with engines that are worked with Cornish, equilibrium or drop valves, especially when driven with trow or loose eccentric. The engineman in making a lift off the bottom, opens the valves wider than when in gear with the eccentric, and any hard grease on the valve spindles may cause the valves to be momentarily suspended; and should one of the valves not gain its seat at the proper time, but from the assigned, or any other cause be suspended, the result will be a contrary action on the engine, which would, in the end, bring the engine up nearly opposite the centre: but should the valve drop to its seat at the same time that the engine is swinging back, the position of the eccentric on the shaft becomes altered, and a complete reversal of the engine takes place; and as this is done in much less time than is taken to describe it, and unattended with noise, unless the engineman's attention is rivetted on his work, there is a great probability of an overwind.

Third Cause.—*Misapprehension on the part of the Engineman.*—Defective indicators for shewing the position of the cage in the shaft cause, at times, overwinding; or, the indicator being placed in some unfavourable position for sight, or a misapprehension on

the part of the engineman as to the true position of the cage in the shaft, before the engine is put in motion. I remember a case which will illustrate this:—At the Old Bottom Colliery, Oldham, near Manchester, two men were at work at the pumps about halfway down the shaft, the proper signal was given to ascend, and the engine put in motion; but the engineman, who was very weary, began to wind as if he was making the full lift from the mine, and the lives of these two men must inevitably have been lost, but for the prompt action of the steam break which I had previously attached. A mistake is soon made, and the steadiest, soberest engineman may mistake the position of the cage, and overwind.

Fourth Cause.—*Disconnection or Breakage of Wheels in second motion Engines.*—At many collieries we find that a train of wheels are connected from the winding engine to the pumping gear, and the drum shaft is capable of being disconnected when not wanted. Many lives have been lost through the drum wheel ungearing, in consequence of an insufficient method of fastening in gear, or neglect of the engineman in properly securing the method adopted. Many accidents have also occurred in consequence of the driving or drum wheel breaking, and the drum by that means being freed from the engine. True there are breaks on drum shafts, but in too many instances they are not in working condition; and I shall shortly shew you, that, with the steam break, the most unwieldy arrangement of break may be worked at every lift from the mine, with advantage.

Fifth Cause.—*Negligence of the Engineman.*—Of this I will say but little, as you all know there are cases of men carelessly neglecting their duty, and where life is at stake we think any arrangement which thoroughly provides against such fatal carelessness, is deserving of the attention of all parties interested in the subject. The self-acting break certainly looks after the engineman, and continually confines him to his duty.

Sixth Cause.—*Sudden incapacity of Engineman, by accident or otherwise.*—We are erecting large engines of enormous capability, for winding both large quantities and with speed, with head gear

and other plant in proportion; and does it not seem reasonable that methods for arresting the motion of these engines, at given periods, should be brought into practice; that a greater margin of safety may be afforded than one man's attention commands. I have known cases of overwinding through a nut flying from the wheel, and stunning the engineman for a few moments; and, seeing that enginemen are not exempt from any sudden sickness, fit, or death, surely this is one argument for the adoption of inventions which shall be a safeguard against all the causes enumerated. Therefore, with your permission, I will proceed to lay before your judgment the self-acting steam break, as an ample provision against all such accidents by overwinding.

Steam is the great agency we employ in raising our coal and ores up the shaft, and if steam is such a tractable agent that we can govern its flow and exhaust, to that nicety which is necessary to work our huge engines and winding tackle, if it is so potent an agent to drive the engine, it is equally powerful to arrest: and with a suitable slide valve, every variation of pressure or amount of application can be attained; in fact, much more by steam than by the usual and (in many cases) clumsy method of applying foot or hand breaks. Steam, as an agent to work the break, possesses the advantage of a continual equality of power to arrest; as there is more or less steam to drive the engine, there is the same pressure to stop it; for, as the steam in the boiler loses or increases in density, and by that means gives a greater or less propelling result on the engine, a corresponding amount of power to arrest the engine is given to the steam break. It is to arrive at this result that we employ an extra cylinder, with slide valve, &c.; and as there are three different actions, or modes of application, totally independent of each other, I will proceed to describe them.

1st.—*The Break applied by the action of the Cams.*—The shaft marked A, is the driving shaft of the machine, conveying motion from the main or crank shaft of the winding engine to a worm which takes into a worm wheel, marked B. This drives the two tappets or cams, situate in the reversing groves marked C C. You

will notice that there is a lever marked D, which is capable of being moved sideways, and transferred into either of the two grooves containing the cams. Wherever practicable, we place the machine opposite the engineman, that the right hand cam and groove may represent the right hand rope; and the left cam and groove, the left hand rope. As the grooves are calculated not to make more than about three quarters of a revolution to a complete lift from the mine, it follows, that on the arrival of a load to the pit's brow, the load is shewn by the corresponding cam which has now lifted up the lever marked D, and brought the break into action. Now, by pushing the lever from the cam sideways to the other groove, that cam being now underneath, shewing the down cage or rope, and the groove under the lever being clear, the reversing lever is permitted to fall into the groove, and thus exhaust the steam, releasing the break. This action takes place at every lift, each cam in turn coming to the top and raising the reversing lever, and by that means bringing the break into action, and seeing that it is connected direct to the engine by tooth and tooth gear, it follows, that certainty of action may be depended on; and this continual lifting of the lever by each cam alternately, we call the action of the break by the cams.

2nd.—*The action of the Break, from the ascending cage in the head gear.*—We have noticed that many cases of overwinding occur from the weight of the down rope, and many occur also, from the thoughtless application of the steam to the wrong side of the piston in the winding engine. I could prove that 50 per cent. of overwinding cases occur to the cages or corves that have already been safely landed, but from starting the wrong way, or by weight of down rope, &c., are brought over the head gear. It will be obvious to you, that whatever protection the action of the cams may afford against direct overwinding, from whatever cause, when the break is released and the engine ready to proceed to the next lift, the cams are no protection against the up cage being drawn over the wheel; therefore, we place a finger in the head gear, in such a position, that, should the cage ascend more than its usual height,

it will be brought in contact with, and lift up the finger, which being connected with the break valve, admits the steam into the break cylinder, and thus brings the break into action in a very sudden and effective manner. This we call the action of the break from the head gear.

3rd.—*The action of the Break from the Foot-plate.*—In ordinary winding, especially with large engines, I have found it preferable to set the cams so that the break shall be applied at two revolutions from the complete lift, and the indicator bell to ring at three; thus giving the engineman one complete revolution after the bell signal to push the lever, marked D, from the full to the empty groove, and to take the engine into his hands to stop her. The slide valve is also peculiar, as the portlip of the valve has a small channel cut in it, that the steam when applied by the cams or foot-plate, causes the piston to ascend slowly, thus bringing the break very gradually into action, and avoiding any too sudden resistance to the engine. The portlip of the valve is also rather broader than the port hole; by this, and in conjunction with the small channel in the lip, we are enabled to apply with the foot, any pressure on the break desirable. For when the break is applied by the foot-plate, the steam only entering by the small channel in the lip, as I said before, a too sudden application is avoided; therefore if the valve is dropped a little at any point of the ascension of the piston, the amount of steam admitted becomes fixed, and the elasticity of the steam admitted keeps on the break in relative strength to the steam applied, until the valve is either dropped lower to exhaust, or raised again to apply the break firmer. We do not depend on the break alone for arresting the engine, but have adopted many plans for cutting the steam from the winding engine. At many engines, exhaust valves are in use for blocking up the steam, and, for one, I would prefer the steam being checked or blocked at the exhaust, as a large engine is much more under control by that means; but in reference to this part of our subject, I will not trespass on your time in explaining all the methods we have used to shut from, or block up, the steam at the winding engine, but will endeavour to explain the best and the

most serviceable for large winding engines, as being applicable to steam or block valves. Attached in some convenient manner to the stem of the foot plate we place a slot, which permits a horizontal bar to slide through with every application of the break; on the bar is a notch or catch which, when the foot plate is not pressed down, is opposite to a pin in the steam or block valves. Now as I before said that the lever marked D can be lifted up by the cams, or by the finger in the head gear, and still the foot plate keeps its position, it follows that whenever the break is applied, by the self-acting arrangement of either cams or the finger in the head gear, the notch or catch on the horizontal bar coming in contact with the pin in the steam or block valves, effectually closes the valve simultaneously with the application of the break. But seeing that the bell gives the signal for the reversing lever to be pushed into the empty groove, the engineman, by attention, need not have the break applied by the cams, but push over the lever in time, and proceed to arrest his engine, and apply the break with his foot in the proper manner, and by so doing, as the foot plate descends with the pressure of the foot, the horizontal bar descends with it, out of the range of the pin on the valve; and when the break is applied, the bar slides along and takes its old position again, without at all interfering with the steam or block valve. I prefer this arrangement before all others, as it is simple, and never out of order when wanted in cases of emergency by neglect or otherwise. This we call the action of the Break from the Foot-plate.

Of Break Materials.—Without attempting to describe any particular arrangement of break levers, &c., perhaps a word on the best materials for the actual friction surface would not be out of place.

It is common in some parts to cover the break bands with wood segments, and let them work against the periphery of either an iron break drum, or the fly wheel of the engine; while in other places old hempen flat rope is preferred before timber segments. Again, many coat the periphery of the break-wheel with wood segments, and allow the iron bands to be without covering, and work

direct against the break-wheel. Certainly covering the periphery of the wheel with wood gives a ready facility for having the wheel true, as it can be turned up. But a break-wheel prepared in this manner with segments, and the bands lined with old hempen flat rope gives out the greatest results of arresting or retarding power with the least amount of pressure or strain, and has the advantage of being almost noiseless.

Together with the steam break we connect an improved Indicator, for showing the position of the cage in the shaft. This is in the form of an ornamented dial, similar to a large clock dial, with the number of revolutions properly set forth, and two fingers, one pointing to the figures showing the numbers of the strokes made, and the other longer, and revolving with every revolution of the crank; and by an indicator of this description, not only is it easy to see the number of strokes made, but the precise position of the crank can be ascertained relative to any mouthing or position in the shaft. It also possesses the merit of being easily adjusted. We also attach a small Recorder or Count, for registering the number of windings made, which is useful, especially where water is required to be lifted during the night; it also affords a ready mode of acquiring a statistical account of the working of the colliery as to how much coal for so many windings. In bringing this paper to a conclusion, I submit to your consideration, that the Steam Break possesses the following qualities:—

1st.—*Easy of application.*—Breaks, such as we in general use, depend upon the manual strength of the attendant for their application; therefore a strong man can exert more breakage power than a weak one: so that what would be sufficient with one would be wanting in the other, and in all cases, depending on the strength of the engineman. Not so the steam break; the slightest movement of the foot puts on the break in a small degree, and it is put on to its full extent as easily, requiring no more manual strength to bring it into full action than a child could exert. It is also a matter of the smallest importance as to the number of

breaks worked by one action of the foot, as, through the medium of steam, it is easy to work the most unwieldy breaks. For instance, in a second motion engine, the break on the engine fly wheel, can be worked in conjunction with the break on the dram shaft, both coupled together, and worked with the greatest ease, thus providing effectually for either disconnection or breakage of wheels, and preventing a run on the dram.

2nd.—*As possessing a variable power, equal to any emergency.*—We contend that a break ought to be put to this test, viz.:—Will it bring up the engine against the steam? If it will not, then the breakage power is deficient, not that there is any need to apply that amount of resistance at every lift, but I doubt not you will agree, that the power ought to be there for an emergency. In the steam break you possess that power, for, as I have before said, what is potent to drive is also equally potent to arrest, and steam, as the steam hammer has shown, is the only agent whereby you can obtain the gentle action of a child, or the wonderful effect of the most violent concussion; for instance, should the engineman bring the cage too high in the head gear, and bring it in contact with the fingers placed there, the slide valve opening wide at the same speed that the cage ascends, the break is instantaneously and effectually applied. Again, what is more awkward, when engaged in shaft work, than having an engine continually creeping, for the want of a proper and proportionate break. But with the steam break no sooner is the signal given than the break can be effectually applied, providing for the engine remaining in the same position until the next signal.

3rd.—*It affords complete Safety in case of Accident to Engineman.*—An engineman is subject to sudden disability or death, as well as to many accidents which may occur in the engine house during the time the lift is being made. The steam break, with the self-acting arrangement, is a perfect safeguard in case of accidents of this description, and nothing is more simple, or less likely to be out of repair; and surely it is true economy to adopt improvements

before the necessity for doing so is shown by actual accident. I argue that, seeing the break is in constant use, and that it is connected with gear to the engine, and that gearing only to lift the valve, we may depend on its always being in working condition, as it is the medium through which the breakage power is exercised.

4th—*Its superiority over any arrangement for disconnecting the Cage.*—Seeing that the cause of overwinding rests in the Engine, we must, in order to obtain certain safety, deal with the motive power; for as the guinea drops quicker than the farthing, so on the same principle the velocity of the cage and the man vary, and should the cage be disconnected at a high velocity life would thereby be in danger.

There is also much to fear from the disengaged end of the rope, which has many times produced fatal results. For, no doubt you are all aware, that life has been lost by overwinding indirectly, or in other words, when the peculiar construction of the head gear has offered a superior resistance to the breakage strain of the rope, what would have been a case of overwinding has become a case of broken rope, and the broken end by lashing about on the pit brow, in the drum, or in the engine house, has caused loss of life and destruction of property. But by the use of the Steam Break neither violent disconnection nor breakage of rope can take place; the Break, in effect, might be represented as saying to the winding engine, "'tis your province to bring the loads to the surface, but beyond the line which I am placed to guard you cannot pass, for the same agent that imparts to you the power to proceed, also, at given intervals, provides me with a much greater power to arrest.

I have endeavoured to explain the action of the Self-Acting Steam Break, and its applicability to colliery Engines in as clear and consise a manner as my abilities will allow; and I can sincerely add that it is without any wish to disparage or ignore any other arrangement for the prevention of accidents by overwinding, but with an earnest desire that the subject may receive at the hands of the coal owners and managers, and others interested, that amount of serious consideration which the safety of life and property demands. And

also a conscientious belief, from many years consideration of the subject that eventually the mining intellect of this country will, amongst other things, direct its energies to the subject, and will recognise the reasonableness of adding to a winding engine an extra steam cylinder, as a governor or determiner to the revolutions of the winding engine, always possessing through all the variable amounts of steam pressure, a sufficient power or check over the winding engine, to thoroughly prevent all accidents by overwinding.

Mr. Menelaus wished to know whether the Break was brought into play upon every occasion of winding, or only in case of accident.

Mr. Ogden said the Break was intended to act at every time, instead of the customary method of attempting to balance the engine by steam. The very principle of the steam break was to work the machine to advantage by throwing the steam into the engine. The break acted at every lift at the second stroke from Monday morning until Saturday night, and if it did not transfer it from the second or third stroke, then at the next stroke the bell rang. Supposing, then, that the engineman was suddenly struck dead, they would have to alter the engine before they could pull the load over.

Mr. Greenwell said that perhaps a word from him in praise of Mr. Ogden's steam break would go farther than something coming from Mr. Ogden himself, because everybody was fond of praising his own invention. He (Mr. Greenwell) had seen the steam break act most effectually. He had seen the engineman act as if suddenly struck down, and, the engine being at full speed, had the break not been attached the full load would have been whisked over the pulley, but instead of this being the case, the break acted most effectually, and everything was brought to a standstill.

Mr. T. Evans said it was almost impossible to over-rate the importance of a steam break. There was a very deep colliery near Manchester—about 660 yards deep—called the Dunkinfield Colliery.

When he last visited the place the steam break was at work. Just before the break was appended an accident of a serious nature occurred there. The engineman had gone away from his engine for the purpose of oiling some part of the machinery, the engine was going at an enormous speed, and the man was thrown right over the engine house into a pond on the other side of the road. This was one instance in which the steam break would have been of most essential service, and it had been attached after the accident which he now spoke of. Another accident recently occurred in Cwm-Neol, where some eight or nine men lost their lives by overwinding, which accident would also have been prevented by the introduction of the steam break. He had not seen the steam break at work in this part of the country, but if it had proved so successful in Lancashire he sincerely hoped it would not be long before it was introduced.

Mr. Rosser asked Mr. Ogden what would be the cost of the steam break, and whether it could be applied to any winding engine.

Mr. Ogden said the cost would be from £25 to £50 for each engine, according to the size of the winding.

Mr T. Evans —A pit, for instance, of 300 yards deep, and a load of 25 Cwt. of Coal at each winding. What would be the cost?

Mr. Ogden said that some engines already had breaks attached to them, and some of them were very good breaks whilst others were of inferior quality. The cost of applying the steam break would depend very much upon the character of the break. If they put a cylinder to act on a break it must be of sufficient weight and strength to resist the action of the cylinder. With a good break the first cost was between £40 and £45. This would include everything complete. A break of £25 value was, generally speaking, found sufficiently strong for anything under 50-horse power, and one of £50 value for anything under 300-horse power.

Mr. Stewart said if any gentleman was on a visit to Bristol, and would go to the Ashton Vale Colliery, the property of Messrs.

Knight and Co., they would see the steam break at work, and he believed it had proved most satisfactory.

Mr. Murphy also spoke of the possibility of an accident happening to the fireman or engineman. About twelve months ago, the man attending to an engine in his neighbourhood fell dead in the night in a fit of appoplexy. He fell into the ashpit, and the only intimation they had of this was by the stoppage of the engine.

Mr. Greenwell said that Mr. Evans just now had asked as to the cost of this steam break He (Mr. Greenwell) had not one word to say in disparagement of Mr. Ogden's valuable invention, because he thought it was a most effectual remedy for accidents of this kind. All he wanted was that Mr. Ogden should cheapen it in some way or other.

Mr. Ogden could not say much with respect to cheapening the application of the steam break, considering he had spent a large sum in making various experiments, before he succeeded in perfecting the machine.

Mr. T. Evans instanced another case which occurred at Llanelly some seven or eight months ago, to show the immense value of the steam break. Although in this case the engineman remained at his engine, yet he could do nothing, in consequence of some derangement in the machinery, the speed of the engine was so great. The consequence was the carriage was drawn over the drum and engine, and the man thrown into the engine house and thereby killed, This took place in the colliery of Messrs. Neville and Co.. one of the best regulated collieries in this part of the country.

Mr. Robson asked if the steam break could be applied to double engines with fly wheels.

Mr. Ogden said it could.

Mr. Huxham had great pleasure in proposing that the best thanks of the meeting be given to Mr. Ogden, and also to Mr. Robson, for their interesting and valuable papers.

The resolution was duly seconded, and upon being put to the meeting, was carried unanimously.

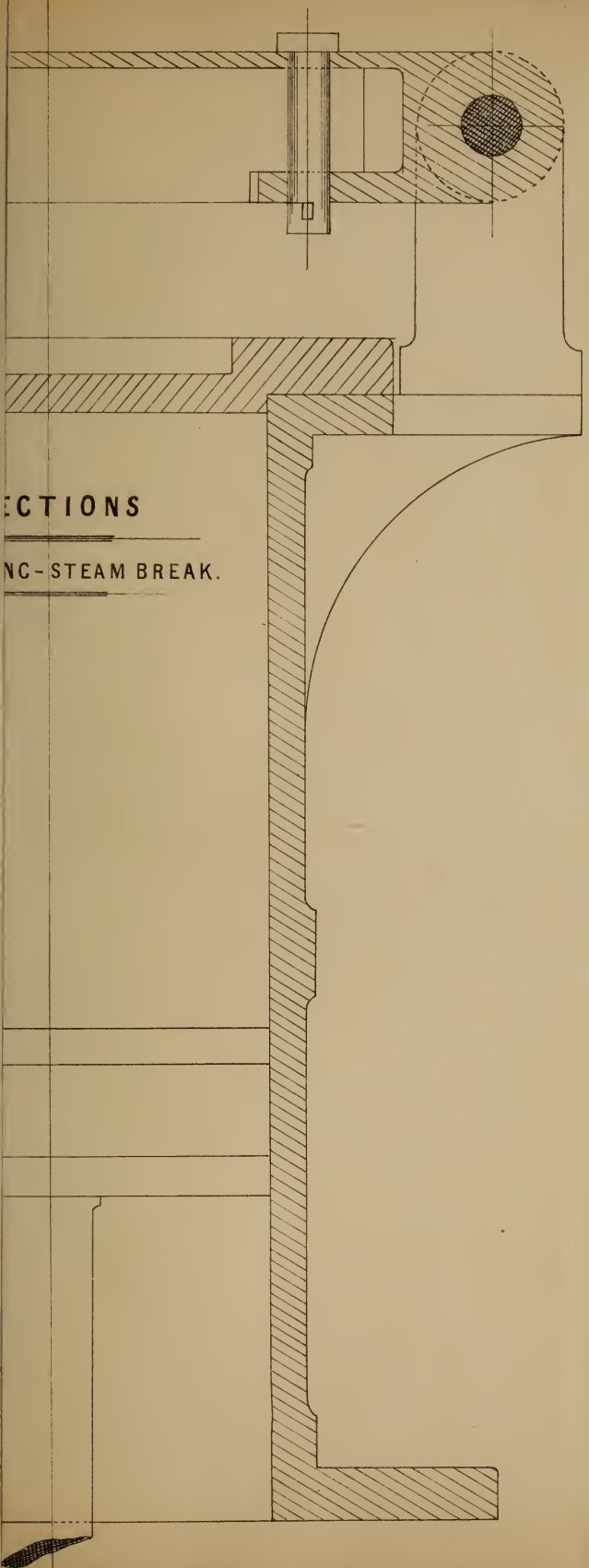
The PRESIDENT said it now became his duty to remind them of the obligation which they owed to the President and Council of the Royal Institution of South Wales, for the use of their excellent rooms. (Hear, hear.) The invitation to hold this meeting there was unsought for by the members of their society, it had been given in the most cordial manner, and carried unanimously at a meeting of the Royal Institution. They did regard the Royal Institution of South Wales as a sister institution, devoted to Practical Science. The friendly manner in which the members of the Institute had been invited to Swansea by the President and Council of the Royal Institution, was a proof, not only of the necessity felt by all for science holding the position already attained, but of every individual member endeavouring actively to forward its interests. He had great pleasure to propose that a cordial vote of thanks be awarded the President, Council, and Members of the Royal Institution of South Wales for the use of their rooms, and their kind invitation.

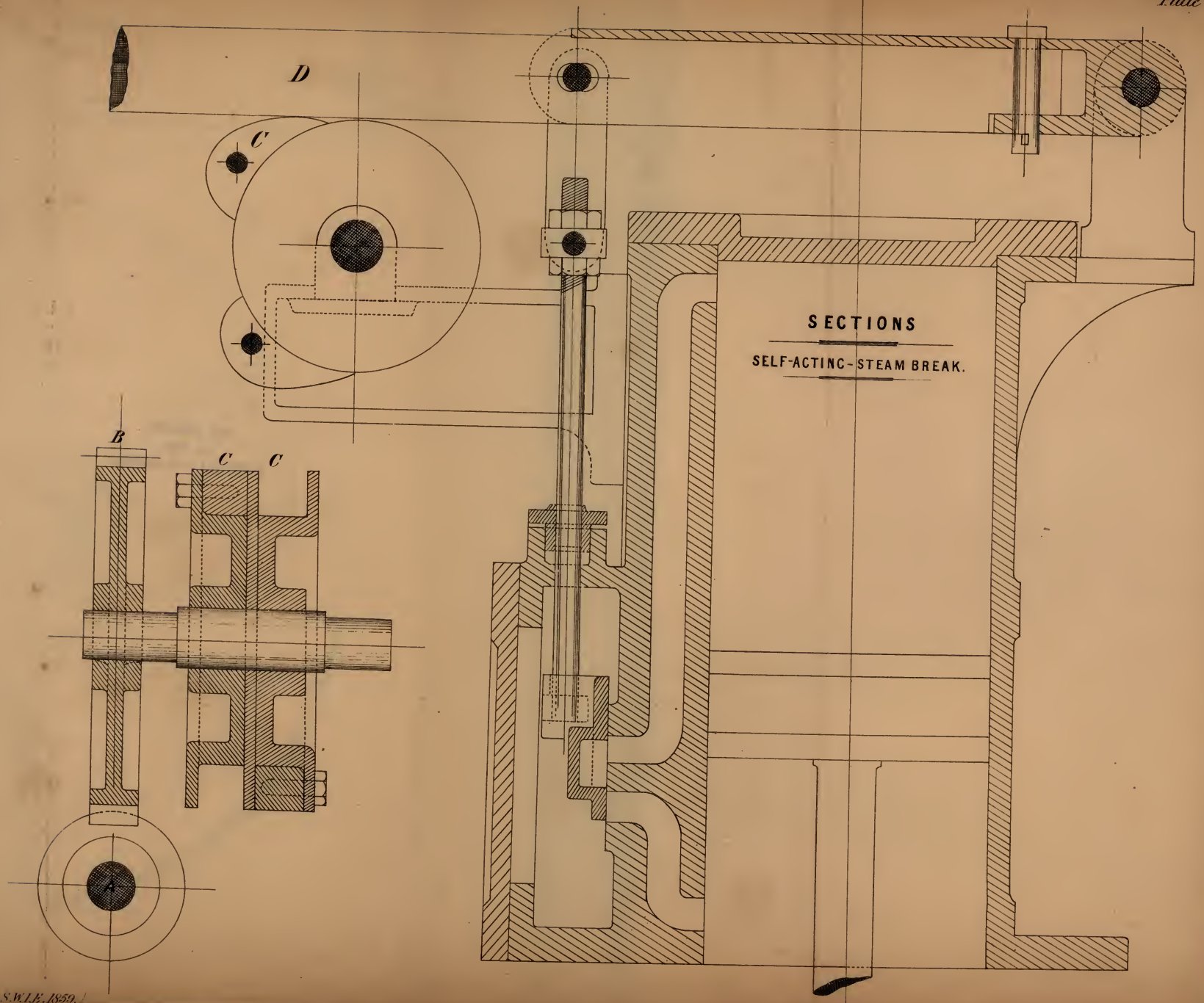
The resolution was duly seconded, and carried most unanimously.

The PRESIDENT ELECT, Mr. W. S Clark, said he begged to propose a vote of thanks to their worthy Chairman, for the great zeal and ability he had shewn in presiding over them, and more especially for the valuable and material aid which he had always rendered the Institute in the shape of contributing papers, &c. He begged to propose a vote of thanks to Mr. Rogers.

The proposition was carried amidst acclamation, after which the members separated.

M. W. White, Printer, 135, High-street, Merthyr-Tydfil.


ECTIONS
NC-STEAM BREAK.


D
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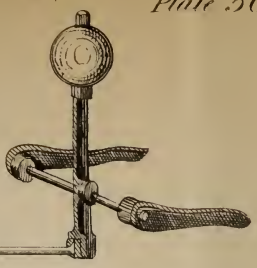
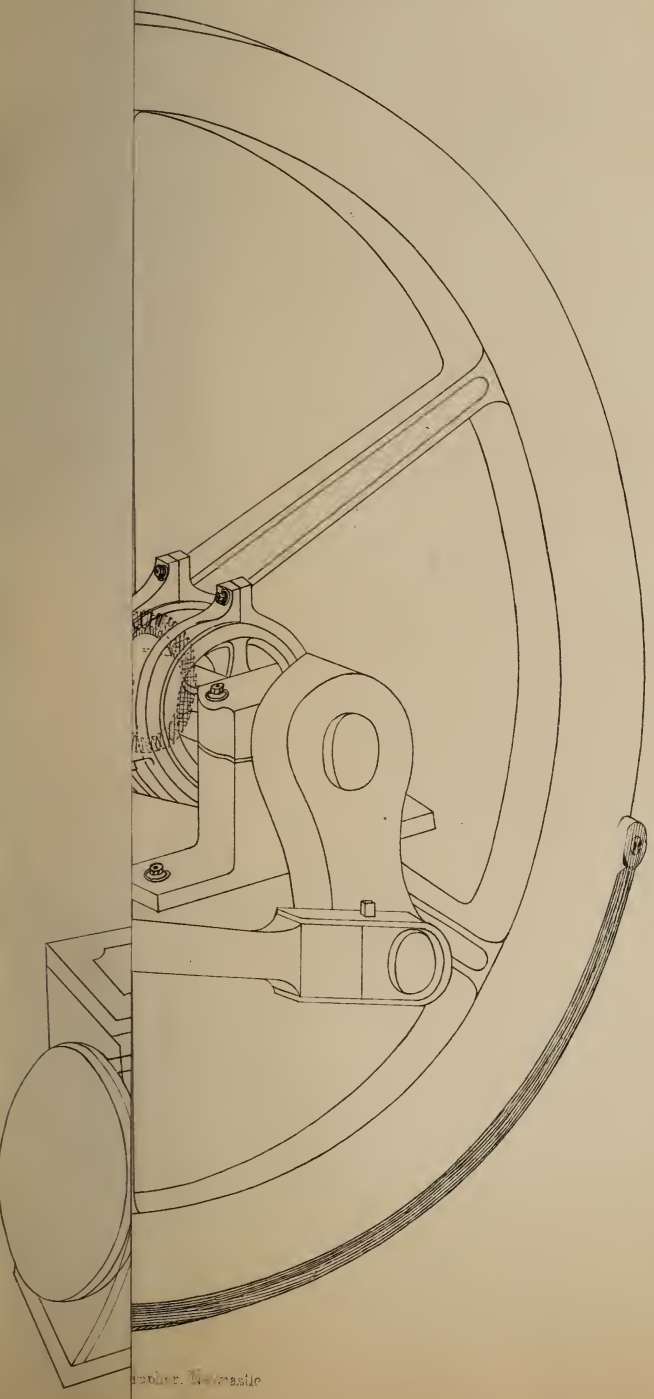
SECTIONS
SELF-ACTING-STEAM BREAK.

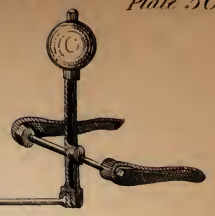
EAK.

gear.





OGDEN'S STEAM BREAK.



Valve-rod from the Head gear.

Self-acting Cams.

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Andrew Reid, Lithographer, Newcastle.

Mr Rogers

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